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ABSTRACT

Instructor guides are provided for each of 11 courses in a 2-year associate degree program in solar technology. The semester-length solar courses are broken down into modules which correspond roughly to a 1- to 2-week block of instruction. Each guide presents a course description, course objectives, references for further information, and a detailed course outline that can be used as the basis for lesson plans. In addition, the guides contain, with some variations, pre-tests, post-tests, answer keys, lab exercises, student assignments, and transparency masters. Guides are provided for the following courses: (1) Introduction to Solar Energy; (2) Energy Science I; (3) Energy Science II; (4) Materials, Materials Handling, and Fabrication Processes; (5) System Sizing, Design, and Retrofit; (6) Collectors and Energy Storage; (7) Energy Conservation and Passive Design Concepts; (8) Operational Diagnosis of Residential Applications; (9) Codes, Legalities, Consumerism, and Economics; (10) Non-Residential Applications and Future Technology; and (11) Practicum in Solar Energy Technology. (AYC)

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SOLAR ENERGY

INSTRUCTOR GUIDES, LABS, & TESTS

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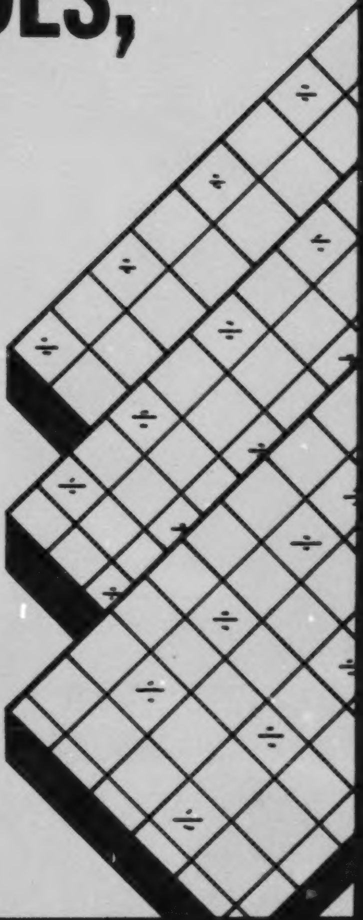

NAVARRO COLLEGE
CORSICANA, TEXAS

INSTRUCTOR GUIDES,

LABS AND TESTS

PROJECT DIRECTOR
Charles G. Orsak, Jr.
Navarro College

TECHNICAL COORDINATORS

William Everet Bolin
North Lake College

Stephen Pomroy
Navarro College

Ray Mudrak
Brevard Community College

Jeff Jacobs
Cerro Coso Community College

Dr. Jim Slater
Malaspina College

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FIRST EDITION

1982

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INSTRUCTOR GUIDES, LABS, AND TESTS

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PREFACE

The United States is facing one of its most challenging decades in recent history. Fuel supply and inflationary prices have forced us to consider alternate energy sources as a means of preserving our standard of living, industrial society, and economic stability. One such alternative is solar.

Presently, foreign crude oil provides the raw material for about one-half the liquid fuel production in the U.S. Political instability in foreign oil-producing countries underscores the need to decrease our ever-growing dependency on foreign energy sources and to lessen our vulnerability to such imports. Solar energy as an alternate can be used as a renewable domestic energy source and to supplement our increasing appetite for oil.

To help bring about the potential for solar energy, there must be a cadre of trained technicians to design, install, troubleshoot, and market solar energy so that the consumer can feel comfortable in the market's ability to service and react to his/her solar energy needs.

With the support of the National Science Foundation, Navarro College, in consortium with North Lake College, Brevard Community College, Cerro Coso Community College, and Malaspina College, has developed and pilot tested a two-year associate degree curriculum to train solar technicians. It can be duplicated or replicated by other educational institutions for their training needs.

The two-year technician program prepares a person to:

1) apply knowledge to science and mathematics extensively and render direct technical assistance to scientists and engineers engaged in solar energy research and experimentation;

2) design, plan, supervise, and assist in installation of both simple and complex solar systems and solar control devices;

3) supervise, or execute, the operation, maintenance and repair of simple and complex solar systems and solar control systems;

4) design, plan, and estimate costs as a field representative or salesperson for a manufacturer or distributor of solar equipment;

5) prepare or interpret drawings and sketches and write specifications or procedures for work related to solar systems; and

6) work with and communicate with both the public and other employees regarding the entire field of solar energy.

This curriculum consists of nine volumes:

1) an Instructor's Guide for the eleven solar courses, to include references, educational objectives, transparency masters, pre-tests and post-tests, and representative student labs;

2) an Implementation Guide addressing equipment, commitment, and elements to be considered before setting up a solar program;

3) Student Material for each of seven of the core solar courses:
    a) Materials, Materials Handling, and Fabrication Processes;
    b) Sizing, Design, and Retrofit;
    c) Collectors and Energy Storage;
    d) Non-Residential Applications;
    e) Energy Conservation and Passive Design;
    f) Codes, Legalities, Consumerism, and Economics;
    g) Operational Diagnosis.

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Throughout this project, many people and institutions have contributed greatly to the development, pilot test, and completion of the solar technology curriculum. First, this project owes a debt of gratitude to the National Science Foundation whose support and encouragement have made this project possible. Specifically, two individuals formerly with the National Science Foundation deserve recognition: Dr. Bill Aldridge and Dr. Gregg Edwards.

Appreciation is extended to thos members who served on the Advisory Committee and provided valuable input to module content, text format, and the pilot test plan and evaluation:

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Ray Mudrak, Brevard Community College, Titusville, Florida.
Stephen Pomroy, Navarro College, Corsicana, Texas.
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USE OF THE INSTRUCTOR GUIDES

The instructor guides contain outlines for each of the eleven solar courses identified in a two-year associate degree in solar technology. Each guide represents a one-semester length course and is divided into various modules which correspond roughly to a one- to two-week block of instruction. The instructor guides are not lesson plans but are outlines from which an instructor can construct lesson plans.

The tabs at the end of this package correspond to the eleven courses contained in this manual. Each of the tabs should be integrated throughout the manual as a handy divider for the material.

Pre-tests, post-tests, and lab exercises are contained in this manual. Each course lists references to which the instructor can go for additional information and text for each of the concepts within the course.

Seven of the eleven courses are supplemented by student materials contained under separate cover. The four not included are: Introduction to Solar Energy, Energy Science I, Energy Science II, and the Solar practicum. (These four student material manuals were left out as a condition of our contract with the National Science Foundation.)

The pagination code for the instructor guides is as follows:

I -- the Roman numeral refers to the specific course within this manual. Each of the eleven courses has its own Roman numeral.

3 -- the Arabic number reflects the specific page within the course, numbered sequentially for each course.

The student maerial corresponds to this numbering scheme but has an "S" between the Roman numeral and the Arabic number to signify that it is from the student material.

The recommended sequence for presenting the two-year associate degree program and the solar courses within it is as follows:

Freshman Year

Fall

Technical Math I
Engineering Drawing I
*Introduction to Solar Energy
*Materials, Materials Handling and Fabrication Processes
*Energy Science I
Educational and Career Planning

Spring

Technical Math II
Composition and Rhetoric
Air Conditioning Principles
*Energy Science II
*Collectors and Energy Storage

Sophomore Year

Fall

Data Entry
Basic Electrical Circuits
Introduction to Business
*System Sizing, Design, and Retrofit
*Energy Conservation and Passive Design Concepts

Spring

Technical Report Writing
General Psychology
*Operational Diagnosis
*Codes, Legalities, Consumerism, and Economics
*Non-Residential Applications and Future Technology
*Practicum in Solar Energy Technology

*Indicates the Solar specific courses within the curriculum.

As a guide to each of the eleven solar courses, each of the course descriptions is listed below:

Introduction to Solar Energy -- The Introduction to Solar Energy presents an overall view of total range of topics to be covered in the two-year curriculum. It covers the relationships between conservation measures, passive solar design, and reduced sizes of active solar systems needed as a result of conservation measures. In addition, it covers the role solar energy can play in the future. It surveys wind energy, photovoltaics, biomass conversion, and other non-solar energy resources.

Energy Science I -- Energy Science I is designed as an introduction to the basic scientific principles needed for solar technology. The course begins as a review of algebra, basic mathematics, and introduction to laboratory operations. The course includes an in-depth study of heat transfer and thermodynamics. Gas laws and psychrometric properties of air are also covered in some depth. The course is based on general physics principles; however, the emphasis is placed on the areas of heat, thermodynamic processes, gases as affected by pressure and temperature, and heat transfer fluids used by active solar systems.

Energy Science II -- Topics covered are: elements of astronomy and geography necessary to understand the variations in solar insolation; the basics of atomic and nuclear physics necessary to understand the sun's processes; the nature of light, its propagation, and devices to collect this solar radiation; and fundamentals of electricity and magnetism and the relation of these principles to AC and DC circuits and devices.

Materials, Materials Handling and Fabrication Processes -- This course introduces the materials, handling procedures, and manufacturing processes that are utilized in the Solar Industry. It includes the basics of plumbing, sheet metal, carpentry, roofing, glazing, concrete pouring, soldering, welding, and other techniques as they are related to the construction of a Solar System. Compatibility and problems encountered with different materials are explored.

System Sizing, Design and Retrofit -- This course presents systematic, detailed methods and procedures for sizing, selection, and installation of solar system components. It also develops skills required to analyze the complete, integrated system including controls and interface with auxiliary conventional systems. Thermal analysis, calculations, human comfort and air properties are an integral part of the course.

Collectors and Energy Storage -- This course introduces the student to the basic information needed for solar system design. It is comprised of a mixture of basic heat transfer theory with application, basic solar hardware description and specification, basic solar system schematics, and simplified solar sizing procedures for solar heated domestic hot water. Both active and passive solar systems are treated.

Energy Conservation and Passive Design Concepts -- The course structure contains nine modules. The basic emphasis in the course is on conservation in personal living, in the design and construction of buildings, and in the equipment utilized in the functioning thereof. The course also places emphasis on the wise use of the sun for space heating and cooling by utilizing active, passive, or hybrid solar systems.

Operational Diagnosis -- This course seeks to bring together the ideas and directions necessary to achieve an adequate level of skills and knowledge in the successful trouble-shooting and repair of solar energy conversion systems.

Codes, Legalities, Consumerism, and Economics -- This course introduces the applicable codes, legal requirements and responsibilities, consumer protection, and business regulations, and government tax exemptions and credits that affect the solar energy industry. The course reviews those regulations imposed on the solar industry before solar energy was introduced and the changes which have taken place to address the solar industry specifically. The course then addresses the government's activity in consumer protection through product testing and standard requirements. Finally, the course evaluates the economics of the solar investment.

Non-Residential Applications and Future Technology -- This course presents non-residential solar energy applications and systems. Specific uses include agricultural, commercial, and industrial sector applications. The loads, temperature requirements, and solar system design are related to various applications in each of the sectors. Laboratory lessons are used to develop the student's skill in designing systems related to the different sector's solar applications. Additionally, possibilities in existing equipment and the development of new systems are discussed.

Practicum in Solar Energy Technology -- This course offers the student an opportunity for a guided work experience. This may be accomplished in either on-campus projects or off-campus activity. Off-campus work experience must have approval of both the college and the employer, and be of a significant level of a solar energy technician. Each student develops a written agreement on the activity to be done. Course credit depends on the level and amount of time required by the activity.

INTRODUCTION TO SOLAR ENERGY

Semester Hours Credit: 2
Lecture: 2
Lab: 0

Project Director:	Charles G. Orsak, Jr.
Prime Author:	Charles L. Younger

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INTRODUCTION:

The Introduction to Solar Energy course presents a systematic overview of energy consumption and the resources currently and potentially useful for meeting the demand. This course is designed to lead the student through a systematic development covering the principles of solar energy conversion as an alternative energy source. Although the primary emphasis is directed toward the distributed or isolated application areas, the student will also be provided an overview of the more significant centralized application and research areas currently in progress. The course content will provide the student with an overview of solar energy technology in sufficient depth for his/her evaluation of future interest areas.

COURSE DESCRIPTION:

The Introduction to Solar Energy presents an overall view of total range of topics to be covered in the two-year curriculum. It covers the relationships between conservation measures, passive solar design, and reduced size of active solar systems needed as a result of conservation measures. In addition, it covers the relationships between energy supply and demand and the relative role solar energy can play in the future. It surveys wind energy, photovoltaics, biomass conversion, and other non-solar energy resources.

OBJECTIVES:

Upon completion of this course, the student should be able to:

(1) Discuss energy and its conversion.

(2) Discuss energy demand and conservation on a world-wide scale.

(3) Identify prime energy resources available at present.

(4) Discuss alternative non-solar energy resources.

(5) Survey solar as an energy source through thermal energy, photovoltaics, passive solar design and active solar design.

MODULE INDEX

Title Page

Energy and Its Conversion..............................I- 7

Energy Demand and Conservation.........................I- 19

Primary Energy Resources...............................I- 29

Alternative Non-Solar Energy Resources.................I- 37

Solar Energy Technology................................I- 49

Solar-Chemical Energy Conversion.......................I- 61

Biomass Energy Technology..............................I- 69

Solar-Mechanical Energy Conversion.....................I- 77

Wind Energy Technology.................................I- 85

Solar-Electric Energy Conservation.....................I- 95

Photovoltaic Energy Technology.........................I-103

Solar-Thermal Energy Conversion........................I-113

Passive Solar-Thermal Energy Technology................I-123

Active Solar-Thermal Energy Technology.................I-131

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Comprehend the flow of energy from source, through conversion, to end use, and the mathematical tools used in discussing energy technology.

(2) Discuss the growth of energy use as influenced by technology and population growth.

(3) Describe and discuss the concept of energy and its relation to work (mechanical energy) and power.

(4) Identify chemical energy conversion as the process accompanying fuel combustion and discuss the efficiency and products of combustion.

(5) Discuss thermal energy, heat transport, and elementary principles of heat engine conversions.

(6) Discuss elementary principles of electrical energy, its generation, and use to produce other forms of energy.

RATIONALE:

Energy technology utilizes a large number of concepts and scientific principles that must be understood for considering the potential role of solar energy. These concepts and scientific principles can be grouped into fundamental categories based on the type of energy input and presented using simple mathematical tools. Comprehension of these basic principles should permit the student to recognize the potentials and limitations of solar energy conversion options.

REFERENCES:

(1) Fowler, John M., Energy-Environment Source Book (updated Edition), National Science Teachers Association, Washington, D.C., 1981.

(2) Priest, Joseph, Energy for a Technological Society (Second Edition), Addison-Wesley Publishing Co., Reading, Massachusetts, 1979.

(3) Bueche, Frederick J., Schaum's Outline of Theory and Problems of College Physics (Seventh Edition), McGraw-Hill Book Co., N.Y., 1979.

(4) Tippens, Paul E., Applied Physics (Second Edition), McGraw-Hill Book Co., N.Y., 1978.

(5) Romer, Robert H., Energy: An Introduction to Physics, W. H. Freeman and Co., San Francisco, California, 1976.

(6) Stoker, H. Stephen and others, Energy: From Source to Use, Scott, Foresman and Co., Glenview, Illinois, 1975.

(7) Butti, Ken and John Perlin, A Golden Thread, Cheshire Books, Palo Alto, California, 1980.

UNIT TITLES:

(1) Energy Measurement
(2) Growth of Energy Use
(3) Energy, Work, and Power
(4) Chemical Energy Conversion
(5) Thermal Energy Conversion
(6) Electrical Energy Conversion

VOCABULARY:

Absolute Zero
Ampere
Annual Rate of Growth
British Thermal Unit
Calorie
Celsius
Chemical Energy
Combustion
Conduction
Convection
Conversion Process
Doubling Time
Efficiency
Electric Current
Electrical Energy
Electrical Resistance
Electrolysis
Electron
Energy
Energy Intensiveness
Exponential Growth
Fahrenheit
Force
Fuel
Generator
Gross National Product
Heat
Heat Engine
Horsepower
Joule
Kilowatt
Kilowatt-hour
Kinetic Energy
Mass
Mechanical Energy
Megawatt
Molecule
Motor
Potential Energy
Power
Radiation
Temperature
Thermal Energy
Voltage
Watt
Work

Reference 1, pp. 103-109
131-149
233-236
283-304
Reference 2, pp. 2-8
363-366
Reference 3, pp. 312-325
Reference 5, pp. 2-42
554-614
Reference 6, pp. 46-58

Unit 1. Energy Measurement - Define and discuss briefly

A. The Flow of Energy
  1. The energy source
  2. Energy conversion
  3. Energy consumption

B. Numbers and Energy Technology
  1. Whole numbers and fractions
    a. Definitions
    b. Positive and negative numbers
    c. Simple and compound fractions
    d. Decimals
  2. Exponents
    a. Definition
    b. Positive exponents
    c. Negative exponents
    d. Zero as an exponent
    e. Fractions as exponents
  3. Large and small number notation
    a. Powers-of-10 notation
    b. Rounding for powers-of-10
    c. Positive exponents
    d. Negative exponents
    e. Prefixes and powers-of-10

C. Dimensions, Units, and Systems
  1. Engineering and international systems
    a. Engineering (English) system
    b. Metric system
    c. International (SI) system
  2. Length and its units
    a. Definition and fundamental basis
    b. Units in various systems
    c. Conversion between systems

    3. Mass and its units
        a. Definition and fundamental basis
        b. Mass and weight
        c. Units in various systems
        d. Conversion between systems
D. Equations
    1. Proportionality and equations
    2. Exponential functions
    3. Doubling time
E. Graphs
    1. Linear scale
    2. Semilogarithmic
    3. Comparison graphs
        a. Histograms
        b. Pie charts
        c. Flow diagrams

STUDENT ACTIVITY	Assignment:
Exercise	Have students set up a special assignments notebook for use throughout the course. Assignments are designed to provide pieces of a puzzle with supporting appendices. Students should prepare:
Reference 1, pg. 286	(1) A diagram for energy flow to and from the earth.
Reference 3, pp. 317, 324	(2) A tabulation of large and small numbers using: a. actual numbers b. power of 10 notation c. rounded number with SI prefix designation.
Reference 5, pg. 559	(3) A tabulation of representative length measures in both engineering and metric units.
Reference 5, pg. 559	(4) A tabulation of representative mass measures in both engineering and metric units.
Reference 1, pg. 235	(5) Representative plots of a simple exponential function using both linear scales and semilogarithmic scales with doubling time indicated on the plots.

Reference 1, pp. 1-9
47-49
131-141
171-173
283-304
Reference 2, pp. 2-8
Reference 5, pp. 591-610
Reference 6, pp. 2-6
33-41
Reference 7, pp. 2-39

Unit 2. Growth of Energy Use - discuss briefly

- A. Historical Development
  - 1. Solar (ancient world)
  - 2. Fire and fuel
  - 3. Muscle power
    - a. Humans
    - b. Animals
- B. Development of Energy Converters
  - 1. Water power
    - a. Water wheel and grinding
    - b. Windmill and pumping
    - c. Water turbine and hydroelectric
  - 2. Steam power
    - a. Steam engine (wood, coal)
    - b. Turbines (fossil fuels, nuclear fuels, electricity)
  - 3. Internal combustion engines
- C. Population Growth
  - 1. Exponential growth
  - 2. Doubling time
  - 3. World population
- D. Population Growth and Energy Demand
  - 1. Effects of technology
    - a. Increased demand
    - b. "Energy intensive" production
    - c. Energy demand and GNP
  - 2. Per capita consumption
    - a. Exponential rise
    - b. Heating, cooling
    - c. Electricity
  - 3. World energy demand

E. End Use of Energy in the U. S.
  1. Residential and commercial sectors
    a. Annual energy consumption
    b. Heating and cooling
    c. Lighting and appliances
  2. Industrial sector
    a. Annual energy consumption
    b. Direct heat
    c. Process steam
    d. Electrical power
  3. Transportation sector
    a. Annual energy consumption
    b. Urban passenger
    c. Inter city passenger
    d. Inter city freight

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their special assignments notebook:
Reference 6, pg. 5	(1) A flow diagram illustrating the historical changes in the power output of energy conversion devices.
Reference 1, pg. 172	(2) Plots on semilogarithmic scales of population growth, energy consumption, and energy consumption per capita.
Reference 5, pp. 603-606	(3) Histograms of pie charts for U.S. energy consumption showing total energy consumed and energy consumed by each economic sector.

Reference 1, pp. 103-106
239-242
Reference 2, pp. 30-43
Reference 3, pp. 25-54
Reference 4, pp. 62-116
Reference 5, pp. 126-145
Reference 6, pp. 17-32

Unit 3. Energy, Work, and Power - briefly discuss:

A. Introduction to Energy Science
   1. Energy conversion
   2. Conservation of energy
   3. Efficiency of conversion

B. Energy Forms
   1. An overview
   2. Kinetic energy
   3. Potential energy

C. Mechanical Energy
   1. Energy of motion
   2. Force and acceleration
   3. Action and reaction

D. Energy and Work
   1. Energy - the capacity to do work
   2. Work - a change in energy
   3. Efficiency defined

E. Energy and Power
   1. Power defined
   2. Mechanical power and units
   3. Electrical power and units

STUDENT ACTIVITY

Exercise

Reference 6, pg. 27

Assignment:

Have students prepare for their special assignment notebook:

(1) A schematic diagram showing the conversion of potential energy to kinetic energy to mechanical energy as suggested by a hydroelectric plant.

(2) Example problems solved illustrating the definitions of work, power, and efficiency and their appropriate units.

Reference 1, pp. 31-38
106-108
Reference 2, pp. 52-91
178-184
Reference 5, pp. 285-291
405-406
583
Reference 6, pp. 54-57

Unit 4. Chemical Energy Conversion

- A. Chemical Reactions
  - 1. Oxidation and combustion
  - 2. Products of combination
    - a. Heat
    - b. Light
    - c. Soot (or its equivalent)
    - d. Gases
    - e. Ashes
  - 3. Fuel for the fire
- B. Solid Fuels
  - 1. Types of solid fuels
  - 2. Heat value
  - 3. Reaction products
- C. Liquid Fuels
  - 1. Types of liquid fuels
  - 2. Heat value
  - 3. Reaction products
- D. Gas Fuels
  - 1. Types of gas fuels
  - 2. Heat value
  - 3. Reaction products
- E. Chemical Fuels
  - 1. Types of chemical fuels
  - 2. Heat value
  - 3. Reaction products

STUDENT ACTIVITY

Exercise

Reference 5, pg. 583

Assignment:

Have the students prepare for their special assignment notebook:

(1) Tables identifying a representative number of each type of fuel (solid, liquid, gas, and chemical), the heating value, and reaction products.

Reference 1, pp. 142-149
245-249

Reference 2, pp. 128-170
185-193
Reference 3, pp. 118-122
134-154
Reference 4, pp. 250-343
Reference 5, pp. 202-270
Reference 6, pp. 17-32

Unit 5. Thermal Energy Conversion

- A. Thermal Energy, Heat, and Temperature
  - 1. Thermal energy defined
  - 2. Heat - thermal energy in transit
  - 3. Temperature - a measure of stored energy
- B. Heat Capacity
  - 1. Specific heat
  - 2. Sensible heat
  - 3. Latent heat
- C. Heat Transport
  - 1. Conduction
  - 2. Convection
  - 3. Radiation
- D. The First Law of Thermodynamics
  - 1. The first law
  - 2. Heat in - no work out
  - 3. Heat in - work out
- E. The Second Law of Thermodynamics
  - 1. The second law
  - 2. Heat engines (cycles)
  - 3. Carnot efficiency

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their special assignment notebook:
Reference 3, pg. 118	(1) A graphical representation of temperature scales from absolute zero to well above the boiling point of water with identification of: the freezing and boiling points of water; the Fahrenheit, Celsius, Rankine, and Kelvin scales; and absolute zero.
Reference 2, pg. 134	(2) A schematic illustrating the first law of thermodynamics.
Reference 2, pg. 136	(3) A schematic illustrating the second law of thermodynamics.

Reference 1, pg. 253-259
Reference 2, pp. 102-110
Reference 3, pp. 171-240, 247
Reference 4, pp. 476-524 544-646, 713
Reference 5, pp. 272-337

Unit 6. Electrical Energy Conversion

A. Fundamentals of Electrical Energy
    1. Charge, current, voltage, and resistance
    2. Electric power
    3. Electric circuits

B. Chemical to Electrical Energy
    1. The battery
    2. Electrolysis
    3. D. C. voltage output

C. Mechanical to Electrical Energy
    1. Moving a wire in a magnetic field
    2. The generator
    3. A. C. voltage output

D. Thermal to Electrical Energy
    1. Thermoelectricity
    2. Thermionics
    3. D. C. voltage output

E. The Reverse Processes
    1. Electrical to chemical energy
    2. Electrical to mechanical energy
    3. Electrical to thermal energy

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their special assignment notebook:
Reference 4, pg. 579	(1) A schematic diagram of a battery circuit showing electrolyte, electrodes, and current flow in the circuit.
Reference 4, pg. 637	(2) A schematic diagram of a simple D.C. electric generator, showing magnetic and electrical components and complete circuit.
Reference 4, pg. 588	(3) A schematic diagram of a thermoelectric circuit, showing hot and cold junctions and complete circuit.
Reference 4, pg. 713	(4) A simple schematic diagram of a thermionic circuit showing the emitter, collector, and complete circuit.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Discuss present and future energy consumption and its relation to people, the economy, and the environment.

(2) Discuss energy consumption, efficiency, and growth demands for the U. S. transportation sector.

(3) Discuss energy consumption, efficiency, and growth demands for the U. S. residential/commercial sector.

(4) Discuss energy consumption, efficiency, and growth demands for the U. S. industrial sector.

(5) Discuss energy consumption, efficiency, and growth demands for U. S. power generation.

(6) Discuss conservation options based on energy flow through the various U. S. economic sectors.

RATIONALE:

Recognizing how our energy is being used and the economic factors associated with this use is essential to any analysis of conservation and alternative energy sources. Although there are several ways to approach this subject, the solar technician should be able to recognize economic sectors which have similar energy demands and can be met with solar energy technology.

REFERENCES:

(1) Fowler, John M., Energy-Environment Source Book, National Science Teachers Association, Washington, D.C., 1975 (updated 1981).

(2) Miller, G. Tyler, Jr., Energy and Environment: The Four Energy Crises (Second Edition), Wadsworth Publishing Co., Belmont, Calif., 1980.

(3) Priest, Joseph, Energy for a Technological Society (Second Edition), Addison-Wesley Publishing Co., Reading, Mass., 1979.

(4) Schurr, Sam H. and others, Energy in America's Future, The John Hopkins University Press, Baltimore, Maryland, 1979.

(5) Stoker, H. Stephen and others, Energy From Source to Use, Scott, Foresman and Company, Glenview, Illinois, 1975.

(6) Singer, S. Fred (compiler), Energy: Readings From Scientific American, W. H. Freeman and Company, San Francisco, Calif., 1979.

UNIT TITLES:

(1) Energy Consumption

(2) The Transportation Sector

(3) The Residential/Commercial Sector

(4) The Industrial Sector

(5) Electric Power Generation

(6) Conservation as an Energy Alternative

VOCABULARY:

Conservation
Economic Sector
Intermediate Load (electrical)
Peak Load (electrical)
Blackout
Catalytic Converter
Energy Intensiveness
Intermediate Energy Form
"Off-peak" Power
Photochemical Smog
Process Steam
Sulfur Smut
Transmission Line
Passenger Efficiency
Smog

Constraint
Annual Rate of Growth
Base Load (electrical)
Brownout
Comfort Energy
Efficiency
Indirect Energy
Load Factor
Particulates
Productivity
Direct Heat
Thermal Pollution
Freight Efficiency
Pollutant

Reference 1, pp. 31-61
283-304
Reference 2, pp. 1-9
35-56
135-148
Reference 3, pp. 2-11
52-86
178-194
370-383
Reference 4, pp. 1-23
34-45
69-124
177-217
Reference 5, pp. 2-12
Reference 6, pp. 8-34

Unit 1. Energy Consumption

A. Energy Flows in Today's Economy
   1. Energy inputs
   2. Distribution of energy inputs
   3. Measures of effective energy use
B. Energy and the Economy
   1. Consumption and economic growth
   2. Conservation versus constraint
   3. Energy and national policy
C. Energy and People
   1. Population growth
   2. Employment
   3. Personal income
D. Energy and the Environment
   1. Threats to the environment
   2. Land and water supply
   3. Radioactive wastes
E. Future Energy Consumption
   1. Future energy demands
   2. Financing future energy supply
   3. Paying for pollution

STUDENT ACTIVITY

Exercise

Reference 1, pg. 285
Reference 6, pg. 24

Reference 1, pg. 143
Reference 5, pg. 324
Reference 6, pg. 25

Assignment:

Have the student prepare for their course assignment notebook:

(1) An energy flow diagram through the U.S. economy identifying:
   a. intermediate form of energy (chemical, mechanical, electrical, thermal)
   b. end use consumption (total)
   c. end use consumption subdivided into useful work and waste.

(2) A chart or histogram comparison of conversion efficiencies for typical energy converters according to intermediate form of energy (chemical to thermal, thermal to mechanical, etc.).

Reference 1, pp. 131-149
283-290
Reference 2, pp. 86-88
Reference 3, pp. 82-86
351-356
Reference 4, pp. 143-159
177-217
Reference 5, pp. 33-44
Reference 6, pp. 8-34

Unit 2. The Transportation Sector

- A. The U. S. Transportation Sector
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- B. Passenger Transportation
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- C. Freight Transportation
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- D. Pipeline Transport
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- E. Problem Areas
  - 1. Air pollution
  - 2. Catalytic converter and fuel economy
  - 3. Ocean and oil spills

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 2, pg. 59	(1) A pie chart (or histogram) showing the energy consumed by the transportation sector compared to the total energy consumed by the U. S.
Reference 2, pg. 59	(2) A pie chart (or histogram) showing the transportation energy breakdown according to transportation mode.
Reference 1, pp. 69, 72 Reference 6, pg. 213	(3) A histogram (or tabulation) comparing efficiencies of various transportation modes.

Reference 1, pp. 131-173
283-290
Reference 4, pp. 69-83
125-143
177-217
Reference 5, pp. 33-41
Reference 6, pp. 8-34

Unit 3. The Residential/Commercial Sector

- A. The U.S. Residential/ Commercial Sector
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- B. Water Heating
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- C. Space Conditioning
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- D. Illumination
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- E. Appliances
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand

STUDENT ACTIVITY

Assignment:

Exercise:

Have students prepare for their course assignment notebook:

Reference 1, pg. 283 Reference 2, pg. 59	(1) A pie chart (or histogram) showing the energy consumed by the residential/ commercial sector compared to the total consumed by the U. S.
Reference 2, pg. 59	(2) Pie charts (or histograms) showing the residential/commercial sector energy breakdown according to principal uses.
Reference 1, pg. 135 Reference 6, pg. 212	(3) A tabulation (or histogram) comparing the efficiencies of typical residential and commercial energy conversion devices.

Reference 1, pp. 131-138
157-171
283-290
Reference 4, pp. 69-83
159-217
Reference 5, pp. 33-44
Reference 6, pp. 8-34

Unit 4. The Industrial Sector

- A. The U. S. Industrial Sector
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- B. Direct Heat
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- C. Process Steam
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- D. Electrical Power
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- E. Raw Materials
  - 1. Energy consumption
  - 2. Energy intensive materials
  - 3. Growth in demand

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 2, pg. 59 Reference 6, pg. 202	(1) A pie chart (or histogram) showing the energy consumed by the industrial sector compared to the total consumed by the U. S.
Reference 6, pg. 204	(2) A pie chart (or histogram) showing the industrial sector energy breakdown according to principal uses.
Reference 1, pg. 137	(3) A tabulation (or histogram) comparing the energy demands for various industrial processes.

Reference 1, pp. 132-149
156-173
197-199
253-259
Reference 2, pp. 35-54
Reference 3, pp. 2-24
102-117
292-295
Reference 4, pp. 269-305
343-397
Reference 6, pp. 8-34

Unit 5. Electrical Power Generation

- A. Electric Utilities as a Consuming Sector
  - 1. Historical development
  - 2. Present consumption
  - 3. Future demands
- B. Electrical Power Generation
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- C. Electrical Energy Storage
  - 1. Nonexistent for generation needs
  - 2. Batteries
  - 3. Pumped storage
- D. Electrical Energy transmission
  - 1. Energy consumption
  - 2. Efficiency
  - 3. Growth in demand
- E. Problem Areas
  - 1. Peaking and load management
  - 2. Fuels and capital for expansion
  - 3. Waste heat

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 6, pg. 202	(1) A pie chart (or histogram) showing the distribution of total energy consumed by the U. S. subdivided by: a. economic sector consumption b. electrical demand by each economic sector.
Reference 1, pp. 134-137	(2) A tabulation typical electrical energy uses by economic sectors.

Reference 1, pp. 65-82
Reference 2, pp. 35-67
149-158
Reference 3, pp. 342-358
Reference 4, pp. 125-176
Reference 5, pp. 308-333

Unit 6. Conservation As An Energy Alternative

A. Conservation Options
   1. Reduced demand
   2. Technology improvement
   3. Alternative energy sources
B. Chemical Energy Conversion
   1. Heat
   2. Light
   3. Power
C. Mechanical Energy Conversion
   1. Heat
   2. Light
   3. Power
D. Electrical Energy Conversion
   1. Heat
   2. Light
   3. Power
E. Thermal Energy Conversion
   1. Heat
   2. Light
   3. Power

STUDENT ACTIVITY

Exercise

Reference 2, pp. 57-66
Reference 5, pp. 309-333

Assignment:

Have students prepare for their course assignment notebook:

(1) A tabulation of energy conservation measures for each of the U.S. economic sectors subdivided according to:
   a. short-term
   b. midterm or transition
   c. long-term measures.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify primary energy resources and their relation to energy conversion processes.

(2) Discuss the nature of hydro resources and the conversion of hydro-energy to mechanical and electrical energy.

(3) Discuss the characteristics of our coal resources, the current and potential use, and the environmental problems of coal use.

(4) Discuss the characteristics of our oil resources and describe the conversion from source through end use of oil products.

(5) Discuss the characteristics of our natural gas resources and describe the conversion from source through end use.

(6) Discuss the nuclear fission process, nuclear power generation, and the problems of radioactive waste.

RATIONALE:

Our current energy resources have established the technology for today's economic sectors. Since this is the base from which the solar technician must work, an overview of the principal characteristics of current energy sources will provide the structure for solar energy technology as an alternative.

REFERENCES:

(1) Fowler, John M., Energy-Environment Source Book, National Science Teachers Association, Washington, D. C., 1975 (updated 1981).

(2) Skinner, Brian J. (Editor), Earth's Energy and Mineral Resources, William Kaufmann, Inc., Los Altos, California, 1980.

(3) Singer, S. Fred (Compiler), Energy: Readings From Scientific American, W. H. Freeman and Company, San Francisco, California, 1979.

(4) Priest, Joseph, Energy For A Technological Society (Second Edition), Addison, Wesley Publishing Company, Reading, Mass., 1979.

(5) Schurr, Sam H. and others, Energy in America's Future, The John Hopkins University Press, Baltimore, Maryland, 1979.

(6) Romer, Robert H., Energy: An Introduction to Physics, W. H. Freeman and Company, San Francisco, California, 1976.

(7) Stoker, H. Stephen and others, Energy From Source to Use, Scott, Foresman and Company, Glenview, Illinois, 1975.

UNIT TITLES:

(1) An Overview

(2) Hydro-Energy

(3) Coal Resources

(4) Oil Resources

(5) Natural Gas Resources

(6) Nuclear Fission Energy

VOCABULARY:

Fossil Fuel
Crude Oil
Coal
Bituminous Coal
Char
Coal Tar
Cracking
High-level Radioactive Waste
Gasoline
High Temperature Gas Reactor
Pressurized Water Reactor
Hydrocarbons
Hydropower
Isotope
Mine Acids
Neutron
Overburden
Pumped Storage
Reserve
Resource
Strip Mining

Petroleum
Natural Gas
Anthracite Coal
Lignite Coal
Coke
Distillate Oils
Fission
Radioactivity
Half-life
Light Water Reactor
Boiling Water Reactor
Hydroelectric
Hydro-energy
Kerosene
Moderator
Nuclear Reactor
Petrochemicals
Recoverable Resource
Residual Fuel Oil
Secondary Recovery
Submarginal Resource

Reference 1, pp. 103-127
185-188
Reference 2, pp. 6-14
Reference 3, pp. 22-34
Reference 4, pp. 14-27
Reference 5, pp. 221-250
269-305
Reference 6, pp. 135-145
Reference 7, pp. 46-58
242-251

Unit 1. Overview
- A. Primary Energy Resources
  - 1. Hydro-energy
  - 2. Fossil fuels
  - 3. Nuclear fuels
- B. Chemical Energy Resources
  - 1. Coal
  - 2. Oil
  - 3. Natural gas
- C. Thermal Energy Resources
  - 1. Chemical energy
  - 2. Nuclear fuels
  - 3. Electrical energy
- D. Mechanical Energy Resources
  - 1. Stream hydro-energy
  - 2. Thermal energy
  - 3. Electrical energy
- E. Electrical Energy Resources
  - 1. Mechanical energy
  - 2. Chemical energy
  - 3. Thermal energy

STUDENT ACTIVITY

Exercise

Reference 1, pg. 131
Reference 6, pg. 24

Assignment:

Have students prepare for their special assignment notebook:

(1) A flow diagram of the paths of energy conversion showing:
- a. primary energy resources
- b. intermediate energy forms
- c. end use energy forms.

Reference 1, pp. 17-18
122-126
156-160
285-287
Reference 4, pp. 37-38
292-295
Reference 5, pp. 315-316
374-375
Reference 6, pp. 135-145
Reference 7, pp. 242-251

Unit 2. Hydro-Energy
- A. Technology
  - 1. Historical development
  - 2. Current uses
  - 3. Future potential
- B. Resources
  - 1. The water cycle
  - 2. Waterfalls
  - 3. Rivers
- C. Conversion
  - 1. Water-diverting structure
  - 2. Turbine
  - 3. Mechanical energy
- D. Distribution
  - 1. Electrical power
  - 2. Mechanical power
  - 3. Pumped storage
- E. Economics
  - 1. Advantages of stream hydro-energy

2. Disadvantages of stream hydro-energy
3. Environmental implications

STUDENT ACTIVITY

Exercise

Reference 4, pg. 35
Reference 7, pg. 27

Assignment:

Have students prepare for their special assignments notebook:

(1) A schematic and flow diagram of hydro-energy conversion showing:
   a. the water head (include both reservoir and pumped storage)
   b. the hydro-mechanical conversion
   c. the mechanical-electrical conversion.

(2) A tabulation of advantages and disadvantages of hydro-energy conversion.

Reference 1, pp. 13-15
113-115
177-188
Reference 2, pp. 6-16
Reference 3, pp. 55-61
Reference 4, pp. 14-17
52-74
Reference 5, pp. 221-250
269-305
343-397
480-512
Reference 6, pp. 357-359
Reference 7, pp. 150-178

Unit 3. Coal Resources
- A. Types of Coal
  1. Anthracite (characteristics)
  2. Bituminous (characteristics)
  3. Lignite (characteristics)
- B. Coal Reserves
  1. Distribution of U. S. coal deposits
  2. Proven and projected U.S. reserves
  3. Proven and projected world reserves
- C. Coal Production
  1. Annual U. S. production
  2. Underground mining
  3. Strip mining
- D. Coal Use
  1. Fuel
  2. Feedstock
  3. Export
- E. Problems Related to Coal Use
  1. Air pollution
  2. Mining methods
  3. Solid form

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their special assignments notebook:

Reference 1, pg. 256
Reference 4, pg. 224

(1) Block diagrams for the production of electricity from coal showing the primary steps from source to end use.

Reference 7, pg. 161

(2) A tabulation of the advantages and disadvantages of coal as an energy source.

Reference 1, pp. 113-127
177-188
Reference 2, pp. 6-14
26-36
Reference 3, pp. 35-44
197-209
Reference 5, pp. 221-250
Reference 7, pp. 59-111

Unit 4. Oil Resources
A. General Characteristics of the Oil Resource
    1. The chemical nature of oil
    2. U. S. oil reserves
    3. World oil reserves
B. Exploration and Recovery Techniques
    1. Exploration techniques
    2. Primary recovery techniques
    3. Secondary techniques
C. Oil Refining
    1. Fractional distillation
    2. Thermal cracking
    3. Polymerization
D. Uses of Oil and Oil Products
    1. Fuels
    2. Lubricants
    3. Feedstocks
E. Problems Associated With Oil Use
    1. Exploration and recovery
    2. Transportation
    3. Pollutants

STUDENT ACTIVITY

Assignment:

Exercise

Have students prepare for their special assignments notebook:

Reference 7, pp. 72, 93

(1) Block diagrams for the production of fuels, lubricants and petrochemical feed stock from oil showing the primary steps from source to use.

(2) A tabulation of the advantages and disadvantages of oil as an energy source.

Reference 1, pp. 113-127
177-188
Reference 2, pp. 6-14
26-36
Reference 3, pp. 35-44
197-209

Unit 5. Natural Gas Resources
A. General Characteristics of the Natural Gas Resource
    1. Chemical composition
    2. Domestic resources and reserves

Reference 5, pp. 221-250
Reference 7, pp. 112-149

3. Unique advantages of natural gas as a fuel

B. Production of Natural Gas
   1. Oil and natural gas
   2. Dehydration
   3. Fractionators

C. Distribution of Natural Gas
   1. Natural gas pipelines
   2. Storage
   3. Storage to user

D. End Uses of Natural Gas
   1. Direct heat
   2. Power generation
   3. Feedstock

E. Problems Related to Natural Gas Use
   1. Growth rate of demand
   2. Price controls
   3. Safety of pipeline system

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their special assignment notebook:

(1) Block diagrams for the production of natural gas and its end use as both heat and electricity (include the primary steps).

(2) A tabulation of the advantages and disadvantages of natural gas as an energy source.

Reference 1, pp. 113-127
177-188
263-270
Reference 2, pp. 6-14
50-82
Reference 3, pp. 67-123
Reference 5, pp. 221-250
269-305
353-397
480-512
Reference 6, pp. 458-476
Reference 7, pp. 186-228

Unit 6. Nuclear Fission Energy

A. General Characteristics of Nuclear Fission Energy
   1. Equivalence of energy and matter
   2. Nuclear fission
   3. Chain reactions

B. Fuels for Nuclear Fission
   1. Uranium
   2. Mining
   3. Enrichment

C. Nuclear Fission Reactors
   1. Components of a nuclear electric power plant
   2. Light water reactors
   3. High-temperature gas-cooled reactors

D. Use of Nuclear Fission Energy

1. Historical development
2. Current nuclear power generating facilities
3. Future potential for nuclear power

E. Problems of Nuclear Fission Energy Use
   1. Reactor safety
   2. Radioactive pollutants
   3. High level wastes

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their special assignments notebook:
Reference 4, pg. 224 Reference 6, pp. 468-470	(1) Block diagrams for the production of electricity from nuclear fuels showing the primary steps from source to electrical output.
Reference 7, pp. 197-200	(2) A tabulation of the advantages and disadvantages of nuclear fuels.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the nuclear breeding phenomena and discuss the potential advantages and disadvantages of nuclear breeders as alternative energy resources.

(2) Describe the nuclear fusion phenomena and discuss the potentials as an alternative energy resource.

(3) Describe the magnetohydrodynamic conversion process and discuss the potential as an alternative energy converter.

(4) Describe the fuel cell and its potential for alternative energy applications.

(5) Discuss geothermal energy, the resources, and methods for converting for commercial applications.

(6) Discuss typical synthetic fuels obtainable from coal, tar sands, and oil shale.

RATIONALE:

There are a number of alternative non-solar resources under investigation which can influence the long range outlook for solar energy applications. The solar technician should be aware of these processes, their possible influence, and the time when significant influence may occur.

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(1) Fowler, John M., Energy, Environment Source Book, National Science Teachers Association, Washington, D. C., 1975 (updated 1981).

(2) Skinner, Brian J. (Editor), Earth's Energy and Mineral Resources, William Kaufmann, Inc., Los Altos, California, 1980.

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(8) Ruedisili, Lon C. and Morris W. Firebaugh (Editors), Perspectives on Energy: Issues, Ideas, and Environmental Dilemmas, Oxford University Press, New York, 1975.

UNIT TITLES:

(1) Nuclear Breeder Reactors

(2) Nuclear Fusion

(3) Magnetohydrodynamics

(4) Fuel Cells

(5) Geothermal Energy

(6) Synthetic Fuels

VOCABULARY:

Magma
Superheated
Flashing
Breeding Reaction
Lithium Breeding
Lawson Criterion
Toroidal
Ohmic
Swelling
Ignition Temperature
Bremsstrahlumg
Tokamak
Laser
Fertile Material
Plutonium
Thermal Breeder
Water Gas
Gasifier
Pyrolysis
Hydrogenation
Liquefaction
Solvent-refined coal
Feedstock
Bitumen
In-situ
Fuel Cell
Electrolyte
Magnetohydrodynamic (MHD)
Liquid Metal Fast Breeder Reactor (LMFBR)
Crystal Plate
Hydrofracturing
Fusion
Deuterium
First Wall
Plasma
Poloidal
Blistering
Coulomb Arrier
Confinement Time
Neutral Beam
Magnetic Mirror
Viscosity
Breeding Ratio
Fast Breeder
Gasification
Producer Gas
Catalyst
Solvation
Methanation
Char
Coalplex
Kerogen
Retort
Fracturing
Electrode
Topping Cycle
Seeding
Electrolysis

Reference 1, pp. 268-270
Reference 2, pp. 50-76
Reference 3, pp. 124-133
Reference 4, pp. 318-325

Reference 5, pp. 295-305
359-360
504-512
Reference 6, pp. 476-482
Reference 7, pp. 200-228

Unit 1. Nuclear Breeder Reactors

- A. Breeding Nuclear Fuels
  - 1. Breeding reactions
    - a. Fast
    - b. Thermal
  - 2. Fertile materials
    - a. Uranium, thorium
    - b. Breeding ratio
  - 3. Doubling time
- B. Fast Breeder Reactors
  - 1. Liquid metal fast breeder reactor
    - a. Physical design (blanket, coolant, heat exchangers)
    - b. Efficiency (fuel, thermal)
    - c. Engineering problems (materials, liquid metals)
  - 2. Gas-cooled fast breeders
    - a. Physical design (similar to HTGR, helium coolant, heat exchangers)
    - b. Breeding ratio, doubling time
    - c. Engineering problems (materials, helium containment)
  - 3. Status of fast breeder reactor development
- C. Thermal Breeder Reactors
  - 1. Light water breeder reactor
    - a. Physical design (similar to PWR, BWR thorium blanket)
    - b. Breeding ratio, doubling time
    - c. Engineering problems
  - 2. Molten salt breeder reactors
    - a. Molten salt fuel
    - b. Physical design
    - c. Breeding ratio, doubling time
    - d. Engineering problems
  - 3. Status of thermal breeder reactor development

D. Advantages of Breeders
  1. Extension of available uranium resources
  2. Abundance of thorium resources
  3. Projected growth of nuclear generating capacity

E. Disadvantages of Breeders
  1. The plutonium hazard
    a. Cancer potential
    b. Clandestine weapon
  2. Transportation of fuel
  3. Thermal pollution

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 1, pg. 269 Reference 6, pg. 480 Reference 7, pg. 204	(1) A schematic and flow diagram of a fast breeder reactor showing principal components.
Reference 2, pg. 52 Reference 3, pg. 133	(2) A tabulation (or histogram) of breeder reactor development projects.

Reference 1, pp. 214-217
Reference 2, pp. 18-19
50-61
Reference 3, pp. 134-148
Reference 4, pp. 325-336
Reference 6, pp. 486-513
Reference 7, pp. 186-191
228-239
Reference 8, pp. 299-335

Unit 2. Nuclear Fusion - Discuss Briefly:

A. Nuclear Fusion Technology
   1. Define nuclear fusion
   2. Fusion reactions
   3. Reaction rates and critical temperatures
B. Nuclear Fusion Energy Resources
   1. Deuterium
   2. Tritium
   3. Lithium
C. Energy Conversion Problems
   1. The Coulomb barrier
   2. Plasma and density
   3. Confinement time
D. Fusion Reactors
   1. Tokamak
   2. Other magnetic confinement
   3. Pellet fusion
E. Economics
   1. Advantages of nuclear fusion
   2. Disadvantages of nuclear fusion
   3. Feasibility to useful power production

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

Reference 2, pg. 51
Reference 3, pp. 144-145

(1) A schematic and flow diagram of a magnetic confined fusion reactor system, showing the principal components.

Reference 2, pg. 53
Reference 3, pp. 146-147

(2) A flow diagram showing the principal tasks to be accomplished versus time for commercial development of fusion power.

Reference 2, pp. 22-23
Reference 4, pp. 301-303
Reference 7, pp. 298-303
Reference 8, pp. 433-443

Unit 3. Magnetohydrodynamics (MHD)

A. Technology of MHD Power Generation
   1. Define MHD power generation
   2. Historical development
   3. Current applications and research
      a. Substitution of ionized gas for rotating conductor
      b. Use as a topping cycle

B. Basic Components of MHD Generators
   1. Superconducting magnets
   2. Electrodes
   3. Ionized hot combustion gases

C. Basic Approaches to MHD Design
   1. Open cycle
   2. Closed cycle
   3. Liquid-metal systems

D. Engineering Problems
   1. Size of magnets
   2. Cost of magnets
   3. Erosion/corrosion

E. Economic Factors
   1. Improved efficiency for electric power generation
   2. Reduced thermal pollution
   3. Reduced air pollution

STUDENT ACTIVITY

Assignment:

Exercise

Have students prepare for their course assignment notebooks:

Reference 7, pp. 298-301

(1) A schematic of a combined MHD-steam turbine power generation system identifying the principal components of the conversion cycle and the flow paths. Include as an insert a schematic of the basic MHD generator.

Reference 1, pp. 199-201
Reference 7, pp. 292-298
Reference 8, pp. 421-432

Unit 4. Fuel Cells - Discuss Briefly:

- A. Fuel Cell Technology
  - 1. Define fuel cell
  - 2. Historical development
  - 3. Current applications and research
    - a. Space program
    - b. Large capacity, central power stations
    - c. Single family dwellings
- B. Basic Components
  - 1. Electrodes
  - 2. Electrolyte
  - 3. Reactants (fuel)
- C. The Hydrogen-Oxygen Fuel Cell
  - 1. Basic chemical reaction
  - 2. Physical structure
  - 3. Output power characteristics
    - a. Current density
    - b. Power
    - c. Efficiency of conversion
- D. Fuel-cell Systems Under Study
  - 1. Reformer-supplied hydrogen and air cells
  - 2. Hydrocarbon-air cells
  - 3. Natural gas-air cells
- E. Problem Areas
  - 1. Catalyst
  - 2. Capital cost
  - 3. Heat transfer

STUDENT ACTIVITY

Exercise

Reference 1, pg. 201
Reference 7, pg. 295

Assignment:

Have students prepare for their course assignment notebook:

(1) A schematic diagram of a fuel cell identifying the principal components of the conversion system.

Reference 2, pp. 144-155
Reference 4, pp. 295-297
Reference 5, pp. 319-321
335-337, 352
Reference 7, pp. 251-262
Reference 8, pp. 352-358

Unit 5. Geothermal Energy

A. Geothermal Energy Technology
  1. Define geothermal energy
  2. Historical development
  3. Current applications
    a. Direct heating
    b. Power generation

B. Energy Resources
  1. Sources of geothermal heat
    a. Magma: core, radioactivity
    b. Geologic "hot spots"
  2. Geographical distribution of geothermal resources
  3. U. S. geothermal resources

C. Hot-water (wet-steam) Systems
  1. Superheated water as heat exchange medium-temperature-depth-pressure relations
  2. Elements of a typical system
    a. Well
    b. Flashing
    c. Chamber
    d. Steam turbine
    e. Generator
  3. Problems of hot-water systems
    a. Corrosion due to impurities
    b. Subsidence

D. Vapor-Dominated (Wet-steam) Systems
  1. Superheated steam as heat exchange medium-temperature-depth-pressure profile
  2. Elements of a typical system
  3. The Geysers (PG & E) as example
    a. Number of generators
    b. Power output cost per KW compared to coal-fired plants

E. Dry Rock Systems
  1. No natural heat-exchange medium-temperature-depth relation
  2. Elements of a typical system
    a. Cold water injection/recovery
    b. Hydrofracturing
  3. Problems
    a. Technology
    b. Development

STUDENT ACTIVITY

Assignment:

Exercise

Have students prepare for their course assignment notebook:

Reference 7, pg. 253
Reference 8, pg. 353

(1) Schematic diagrams illustrating the formation of geothermal resources with identification of the principal types of geothermal systems.

Reference 7, pp. 256-257

(2) Schematic flow diagram of geothermal energy conversion identifying the principal components of the conversion process.

Reference 1, pp. 117-118
191-194
Reference 2, pp. 37-47, 73
Reference 3, pp. 48-53
Reference 4, pp. 299-301

Reference 5, pp. 251-268
347-351
516-528
Reference 7, pp. 94-104
140-144
178-184
Reference 8, pp. 377-396

Unit 6. Synthetic Fuels

A. Synthetic Fuels Technology
  1. Define synthetic fuels
    a. Coal
    b. Tar sands
    c. Oil shale
  2. Historical development
    a. Water gas
    b. Producer gas
  3. Current applications and potential

B. Tar Sands
  1. Definition and geographic distribution
  2. Resource exploitation
  3. Refining and product output

C. Oil Shale
  1. Definition and geographic distribution
  2. Resource exploitation
  3. Refining and product output

D. Coal Gasification
  1. Definition and feedstock
  2. Gasification processes-Lurgi process
  3. Product output and potential

E. Coal Liquefaction
  1. Definition and feedstock
  2. Liquefaction processes-COED process
  3. Product output and potential

STUDENT ACTIVITY

Exercise

Reference 3, pp. 49-50

Reference 7, pg. 103

Assignment:

Have students prepare for their course assignment notebook:

(1) Schematic flow diagrams for the conversion of coal to synthetic fuels showing the principal conversion steps and end products.
Flow diagrams:
a. carbonization process
b. direct hydrogenation process
c. extraction process
d. Fischer-Tropsch process.

(2) Flow diagram for the extraction of hydrocarbons from tar sands, identifying the principal conversion steps.

Reference 7, pp. 100-101

(3) Flow diagram for the processing of oil shale showing the conversion processes from source to end products.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify solar energy by primary and secondary modes and principal modes of conversion for end uses.

(2) Discuss the current model of the sun, its thermonuclear reactions, and the energy output as a typical blackbody radiator.

(3) Describe the earth-sun motions and discuss the solar insolation from sun to earth and its relation to wind, water, and sunshine at the earth's surface.

(4) Trace the historical development of the direct uses of solar energy, which laid the foundation for today's passive systems, flat plate collectors, and concentrating collectors.

(5) Trace the historical development of solar water heating and comprehend why these devices failed to gain more widespread use.

(6) Trace the historical development of solar engines and comprehend why these devices failed to gain more widespread use.

RATIONALE:

The flow of energy from the sun to the earth and the sun-earth relations form the basis for using solar energy. Comprehension of those factors which influence the collection, conversion, and end use of solar energy are essential for the solar technician. It is equally important that the solar technician recognize that solar energy use is not a new technology and understand why historical devices failed to gain more widespread use.

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(1) McDaniels, David K., The Sun: Our Future Energy Source, John Wiley and Sons, New York, 1979.

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(7) Abell, George, *Exploration of the Universe (Updated Brief Edition)*, Holt, Rinehart and Winston, New York, 1973.

(8) Lunde, Peter J., *Solar Thermal Engineering*, John Wiley and Sons, New York, 1980.

(9) Mazria, Edward, *The Passive Solar Energy Book*, Rodale Press, Emmaus, Pennsylvania, 1979.

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(11) Kreider, Jan F. and Frank Kreith (Editors), *Solar Energy Handbook*, McGraw-Hill Book Co., New York, 1981.

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(13) Meinel, Aden B. and Marjorie P. Meinel, *Applied Solar Energy*, Addison-Wesley Publishing Company, Reading, Massachusetts, 1976.

(14) Merrill, Richard and Thomas Gage (Editors), *Energy Primer: Solar, Water, Wind and Biofuels (Updated and Revised Edition)*, Dell Publishing Co., New York, 1978.

UNIT TITLES:

(1) Solar Energy Technology

(2) The Solar Furnace

(3) Sun-Earth Relations

(4) Early Utilization of Solar Energy

(5) Development of Solar Water Heating

(6) Solar Power Development

VOCABULARY:

Hertzsprung-Russell (HR) Diagram
Star
Nova
Neutron Star
Galaxies
Astronomical Unit
Thermonuclear
Triple Alpha Cycle
Photosphere
Corona
Solar Prominence
Blackbody
Electron Volt
Spectrum
Wave Frequency
Wave Length
Ecliptic
Perihelon
Winter Solstice
Autumnal Equinox
Sun Time
Infrared
Ultraviolet
Mesosphere
Stratosphere
Biosphere
Lithosphere
Cloud
Density
Convection Currents
Greenhouse Effect
Climate
Horizon
Azimuth
Longitude

Big-bang Theory
Red Giant
Supernova
Black Hole
Milky Way
Light-year
Proton-proton Cycle
Carbon Cycle
Chromosphere
Sunspot
Solar Flare
Photons
Electromagnetic Waves
Velocity of Light
Wave Motion
Wave Period
Aphelion
Summer Solstice
Vernal Equinox
Hour Angle
Solar Constant
Light Spectra
Earth's Atmosphere
Ionosphere
Troposphere
Hydrosphere
Ozone
Wind
Pressure
Coriolis Effect
Weather
Zenith
Altitude
Latitude
Insolation

Beam Radiation
Scattering
Pyrheliometer
Commercialization
Diffuse Radiation
Pyranometer
Passive

Reference 1, pp. 16-17
78-83
Reference 2, pp. 18, 105-108
113, 205-214
Reference 3, pp. 114-133
Reference 4, pp. 1-20
Reference 5, pp. 555-628
715-771
1279-1297
Reference 14, pp. 8-13

Unit 1. Solar Energy Technology

A. Define Solar Energy Technology
   1. Solar energy for heating
   2. Solar energy for power generation
   3. Solar energy for fuel production
B. Solar Energy Resources (General Overview)
   1. Radiation - a primary resource
   2. Wind and water - secondary resources
   3. Photochemical - a secondary resource
C. Solar Energy Conversion (General Overview)
   1. On-site methods
   2. Distributed methods
   3. Centralized methods
D. Distribution of Converted Solar Energy
   1. Direct use
   2. Power generation
   3. Storage
E. Economics of Solar Energy Conversion (General Overview)
   1. Advantages
   2. Disadvantages
   3. Possible impact as an alternative energy source

STUDENT ACTIVITY

Exercise

Reference 1, pg. 286
Reference 5, pg. 740
Reference 14, pg. 9

Assignment:

Have students prepare for their course assignment notebook:

(1) An energy flow diagram from the sun through the atmosphere and conversion processes to end use categories. The principal conversion steps are to be identified.

Reference 1, pp. 87-114
Reference 6, pp. 637-688
Reference 7, pp. 303-319
338-356
360-383

Unit 2. The Solar Furnace

- A. Stars and The Sun
  - 1. The universe
  - 2. The Milky Way
  - 3. The sun
- B. The Solar Furnace
  - 1. Life cycle of a star
  - 2. The proton-proton thermonuclear reaction
  - 3. The triple-alpha and carbon-nitrogen thermonuclear reactions
- C. Inside The Solar Sphere
  - 1. The core region
  - 2. Radioactive transport region
  - 3. The photosphere
- D. The Sun's Atmosphere
  - 1. The chromosphere
  - 2. The corona
  - 3. Sunspots, prominences, flares
- E. The Sun's Energy Output
  - 1. Blackbody radiation
  - 2. Waves and the electromagnetic spectrum
  - 3. Photons and the electron volt

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 1, pg. 96	(1) A schematic illustration of the various regions of the sun, identifying each principal region as to relative size. Include inserts:
Reference 1, pg. 94 Reference 6, pg. 64	1. A schematic illustration (or equation) representing the thermonuclear proton-proton cycle with its temperature.
Reference 1, pg. 113	b. A schematic illustration of the blackbody radiation from the photosphere with its temperature.
Reference 1, pg. 100	c. A schematic illustration of the electromagnetic spectrum.

Reference 1, pp. 97, 117-127
Reference 7, pp. 84-106
Reference 8, pp. 62-114
Reference 9, pp. 267-300
Reference 10, pp. 49-94
103-136
Reference 14, pp. 30-52

Unit 3. Sun-Earth Relations

A. The Earth's Revolution About the Sun
  1. The earth's orbital motion
    a. Elliptical orbit and period
    b. Aphelion and perihelion
  2. Seasons and sunshine
    a. Latitude and the earth's equator
    b. The solstices
  3. The solar constant
    a. Average and annual variation
    b. Spectral (wave and photon) distribution

B. The Earth's Rotation
  1. The skydome
    a. Zenith and horizon
    b. Sun's altitude and azimuth
  2. The passage of time - hour angle
    a. Degrees
    b. Minutes
  3. Solar time and earth time
    a. Longitude
    b. Equation of time

C. The Earth - Nature's Natural Passive System
  1. The atmosphere
    a. Temperature,
    b. Moisture
    c. Wind
  2. The hydrosphere
    a. temperature
    b. Current
    c. Waves
  3. The lithosphere and biosphere
    a. Climate
    b. Weather
    c. Pollutants

D. The Earth's Surface Sunshine
  1. Components of earth's solar radiation
    a. Define insolation
    b. Short waves - beam and diffuse

        c. Long waves
    2. Atmospheric attenuation of solar constant
        a. Scattering and spectral distribution
        b. The sunshine index (air mass ratio)
    3. Collector orientation
        a. Latitude
        b. Tilt angles
E. Measuring the Insolation
    1. Pyranometer
    2. Pyrheliometer
    3. Sources for measured insolation data

STUDENT ACTIVITY	**Assignment:**
Exercise	Have students prepare for their course assignment notebook:
Reference 7, pp. 98-99	(1) A schematic illustration of the earth's revolution about the sun identifying the earth-sun relation at each solstice and equinox. Include inserts showing the earth-latitude interception of the sun's radiation at each solstice and equinox.
Reference 7, pp. 86-88 Reference 9, pp. 269-27	(2) Schematic illustrations of the earth's skydome defining latitude, longitude, zenith, horizon, altitude, and azimuth.
Reference 9, pp. 279-290	(3) A sun chart for the local latitude showing the monthly sun path by time of day. Include as an insert: a plot of the equation of time and the defining equation for local time to sun time correction.
Reference 1, pg. 123 Reference 7, pg. 101 Reference 14, pg. 46	(4) A schematic illustration of a flat and tilted surface with respect to the sun's rays.

Reference 1, pp. 67-78
Reference 11, pp. 1-1 - 1-8
Reference 12, pp. 2-59
Reference 13, pp. 1-25

Unit 4. Early Utilization of Solar Energy

- A. Ancient Greece
  - 1. The sundial and solar architecture
  - 2. Passive heating and cooling
  - 3. Solar architecture and urban planning
- B. Ancient Rome
  - 1. Glass as a solar heat trap
  - 2. Solar heat storage
  - 3. Sun-rights laws
- C. Solar Heat Traps
  - 1. The fruit wall
  - 2. Greenhouses
  - 3. Solar hot boxes
- D. Solar Energy Concentrators
  - 1. Plane mirrors
  - 2. Concave mirrors
  - 3. Focusing lenses
- E. Application of Concentrators
  - 1. Fire ignition
  - 2. Solar ovens
  - 3. Solar furnaces

STUDENT ACTIVITY

Exercise

Reference 11, 12, and 13

Assignment:

Have students prepare for their course assignment notebook:

(1) A chronological tabulation of the use of passive solar energy methods identifying the principal technology contributions for each period.

Reference 11, pp. 1-16 - 1-24
Reference 12, pp. 115-155

Unit 5. Development of Solar Water Heating

- A. Bare Tanks and Water Heating
  - 1. Type, size and positioning
  - 2. Heat gain problems
  - 3. Heat loss problems
- B. Enclosed Tanks and the Collector
  - 1. Type, size and positioning
  - 2. Hot water and supply
  - 3. Heat loss problems

C. Improvements in the Collection
    1. Improvements in collector and insulation
    2. Reflector enhancement of solar energy
    3. Thermal stratification in tank

D. The Early Hot Water Systems
    1. Solar collector and storage tanks
    2. Thermosiphon system
    3. Closed-loop systems

E. Economic Ups and Downs
    1. The first boom, 1923
    2. 1932 to World War II
    3. Postwar decline

STUDENT ACTIVITY

Assignment:

Exercise

Have students prepare for their course assignment notebook:

Reference 11, 12

(1) A chronological tabulation of the development of solar water heating identifying the principal contributions for each period.

Reference 1, pp. 67-78
Reference 11, pp. 1-8 - 1-16
Reference 12, pp. 63-111
Reference 13, pp. 1-25

Unit 6. Solar Power Development

A. Mouchot's Solar Engines, 1860-1880
    1. Description of solar systems
    2. Performance of engines
    3. Failure of commercialization

B. Ericsson's Solar Engines, 1870-1889
    1. Description of solar systems
    2. Performance of engines
    3. Failure of commercialization

C. Eneas' Solar Engines, 1899-1904
    1. Description of solar systems
    2. Performance of engines
    3. Failure of commercialization

D. Willsie and Boyle, 1902-1911
   1. Description of solar systems
   2. Performance of engines
   3. Failure of commercialization

E. Shuman's Near Commercial Success, 1906-1917
   1. Description of solar systems
   2. Performance of systems
   3. Failure of commercialization

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 11, 12, and 13	(1) A chronological tabulation of the development of solar engines and power systems identifying the principal contributions for each period.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Comprehend the fundamental principles of solar-chemical energy conversion and discuss the advantages, disadvantages, and potentials for this area of technology.

(2) Discuss the photosynthesis phenomenon as a natural process and the problems associated with laboratory conversion processes.

(3) Discuss the photochemical phenomenon and its potential as a solar-chemical energy conversion process.

(4) Discuss the significant uses of alcohol, elementary fundamentals of production, and the potential for a solar-chemical energy conversion process.

(5) Discuss the significance of methane, elementary fundamentals of production, and the potential for a solar-chemical energy conversion process.

(6) Discuss the significance of hydrogen as an alternative fuel, elementary fundamentals of its production, and the potential for a solar-chemical energy conversion process.

RATIONALE:

Chemical energy is the basis for the greater percentage of end use energy generation by direct combustion to provide heat or indirect combustion to provide input for mechanical and electrical power. The potential energy sources include refined products from fossil fuel sources. Solar energy can interact directly with various forms of matter and through chemical reactions produce end products that are comparable to fossil fuel products. The solar technician should be knowledgeable of the methods currently under investigation and the potential for solar-chemical energy conversion as an alternative energy resource.

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(1) Kreider, Jan F. and Frank Kreith (Editors), Solar Energy Handbook, McGraw-Hill Book Company, New York, 1981.

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(5) Fowler, John M., *Energy-Environment Source Book*, National Science Teachers Association, Washington, D. C., 1975 (updated 1981).

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(10) Parker, Sybil P. (Editor-In-Chief), *McGraw-Hill Encyclopedia of Energy (Second Edition)*, McGraw-Hill Book Company, New York, 1981.

(11) Cheremisinoff, Paul N. and Thomas C. Regino, *Principles and Applications of Solar Energy*, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1978.

UNIT TITLES:

(1) Solar-Chemical Energy Conversion Technology

(2) Photosynthesis Technology

(3) Photochemical Technology

(4) Alcohol Technology

(5) Methane Technology

(6) Hydrogen Technology

VOCABULARY:

- Alcohol
- Wood Alcohol
- Ethyl Alcohol
- Gasohol
- Fermentation
- Aerobic
- Algae
- Bacteria
- Composting
- Fungus
- Biochemical Process
- Electrochemical Process
- Primary Productivity
- Nitrogen Fixation
- Electron Donor
- Photochemical
- Aquadic
- Municipal Waste
- Forest Waste
- Solid Waste
- Solar-chemical Energy
- Photosensitive
- Methanol
- Grain Alcohol
- Ethanol
- Distillation
- Anaerobic
- Agricultural Waste
- Animal Feed Lot
- Biodegradable
- Decomposer
- Microorganism
- Thermochemical Process
- Photosynthesis
- Carbon Fixation
- Quanta
- Electron Acceptor
- Photochemical Cell
- Biomass
- Organic Compounds
- Sludge
- Urban Waste
- Secondary Chemical Fuel

Reference 2, pp. 120-133
Reference 3, pp. 154-161
196-226
Reference 4, pp. 54-57
Reference 6, pp. 126-132
Reference 7, pp. 715-771
905-937
1005-1057
1137-1144
Reference 11, pp. 141-170

Unit 1. Solar-Chemical Energy Conversion Technology - Discuss Briefly:

- A. Overview of Solar-Chemical Conversion
  1. Definition (solar to secondary chemical fuel)
  2. Natural process (photosynthesis)
  3. Synthetic process (photochemical)
- B. Energy Resources
  1. Solar insolation
  2. Primary chemical resources (biomass)
  3. Secondary chemical resources (photosensitive)
- C. Energy Conversion
  1. Biochemical processes
  2. Thermochemical processes
  3. Electrochemical processes
- D. Energy Distribution
  1. Gaseous fuels
  2. Liquid fuels
  3. Solid fuels
- E. Economics
  1. Advantages
  2. Disadvantages
  3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

1. A glossary of terms/terminology set forth in module vocabulary.

Reference 1, Chapter 25
Reference 2, pp. 125-133
Reference 3, pp. 154-161
Reference 4, pp. 50-53
Reference 5, pp. 106-108
206-208
Reference 7, pp. 1005-1057
Reference 8, pp. 222-228
Reference 9, pp. 130-145
Reference 11, pp. 157-164

Unit 2. Photosynthesis Technology - Discuss Briefly

- A. Overview of Photosynthesis Conversion
  1. Definition (a natural process)
  2. Historical development
  3. Current applications
- B. Energy Resources
  1. Solar insolation
  2. Plant species
  3. Soil, water, and fertilizers

C. Energy Conversion
    1. Photosynthetic conversion of sunlight
    2. Carbon and nitrogen fixation
    3. Primary productivity
D. Energy Distribution
    1. Food and fiber crops
    2. Aquatic plant species
    3. New plant species for biomass conversion feedstock
E. Economics
    1. Advantages
    2. Disadvantages
    3. Future potential

STUDENT ACTIVITY

Exercise

Reference 2, pg. 126
Reference 3, pg. 157
Reference 7, pp. 1049, 1050, 1054

Assignment:

Have students prepare for their course assignment notebook:

(1) A flow diagram from energy source to energy distribution for photosynthetic conversion, including:

the basic photosynthetic cycle (carbon fixation).

Reference 2, pp. 93-94 129-132
Reference 7, pp. 1029-1033
Reference 8, pp. 216-238
Reference 9, pp. 142-145

Unit 3. Photochemical Technology - Discuss Briefly:

A. Overview of Photochemical Conversion
    1. Definition (a synthetic photosynthetic process)
    2. Historical development
    3. Current applications
B. Energy Resources
    1. Solar insolation
    2. Electron donors
    3. Electron acceptors
C. Energy Conversion
    1. Requirements for useful photochemical reaction
    2. The photochemical cell
    3. Efficiency of the conversion process
D. Energy Distribution
    1. Direct fuel production (hydrogen)
    2. Electrical energy
    3. Thermal energy
E. Economics

    1. Advantages
    2. Disadvantages
    3. Future potential

STUDENT ACTIVITY

Exercise

Reference 2, pp. 128-132
Reference 7, pp. 1056, 1057

Reference 3, pp. 208-213
Reference 2, pp. 122-124
127
Reference 6, pp. 128-129
Reference 7, pp. 728-731
750-755
1015-1020
1052
Reference 10, pp. 290

Assignment:

Have students prepare for their course assignment notebook:

(1) A schematic flow diagram from source through conversion to energy distribution of the photochemical conversion process.

Unit 4. Alcohol Technology - Discuss Briefly:

A. Overview of Alcohol Technology
    1. Definition of alcohol
    2. Ethanol (grain alcohol)
    3. Methanol (wood alcohol)

B. Resources for Alcohol
    1. Fossil fuels
    2. Cultivated crops
    3. Organic wastes

C. Resource Conversion
    1. Distillation
    2. Fermentation
    3. Anaerobic digestion

D. Distribution of Alcohol
    1. Chemicals
    2. Motor fuel
    3. Lighting and heating

E. Economics of Alcohol Technology
    1. Advantages
    2. Disadvantages
    3. Future potential

STUDENT ACTIVITY

Exercise

Reference 3, pp. 208, 210
Reference 2, pg. 127

Reference 1, Chapter 6
Reference 2, pp. 123-124
Reference 3, pp. 154-161
196-203
Reference 6, pp. 128-129
Reference 7, pp. 1059-1089

Assignment:

Have students prepare for their course assignment notebook:

(1) A schematic flow diagram for alcohol technology covering source to end use.

Unit 5. Methane Technology - Discuss Briefly:

A. Overview of Methane Technology
    1. Definition of methane
    2. Historical development

Reference 11, pp. 141-170

STUDENT ACTIVITY

Exercise

Reference 1, pp. 25-12
Reference 3, pp. 159-196
Reference 11, pg. 168

Reference 1, pp. 6-30 - 6-34
Reference 2, pp. 130-132
Reference 4, pp. 282-292
Reference 7, pp. 905-921
1137-1144
Reference 8, pp. 247-250
Reference 10, pp. 326-330
Reference 11, pp. 141-155

3. Current applications

B. Energy Resources
    1. Naturally occurring (brief review)
    2. Synthetic fuels (brief review)
    3. Biomass (brief review)

C. Energy Conversion
    1. Biochemical
    2. Thermochemical
    3. Electrochemical

D. Energy Distribution
    1. Gaseous fuel
    2. Chemicals
    3. Petrochemical feedstock

E. Economics
    1. Advantages
    2. Disadvantages
    3. Future potential

Assignment:

Have students prepare for their course assignment notebook:

(1) A flow diagram from source, through conversion, to end product for methane technology.

Unit 6. Hydrogen Technology
Discuss briefly:

A. Overview of Hydrogen Technology
    1. Hydrogen as an alternative fuel
    2. Historical development
    3. Current applications

B. Hydrogen Resources
    1. Water
    2. Hydrocarbons
    3. Biomass

C. Resource Conversion
    1. Electrolysis
    2. Thermochemical processes
    3. Photochemical processes

D. Hydrogen Distribution
    1. Gaseous fuel
    2. Solar energy storage
    3. Industrial processes

E. Economics of Hydrogen Technology
    1. Advantages
    2. Disadvantages

3. Future potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 1, pp. 6-32	(1) A schematic flow diagram for the electrolytic production of hydrogen from the electrical course, through the electrolysis module, to the hydrogen gas output.
Reference 4, pg. 285	(2) A schematic flow diagram comparison of hydrogen as a fuel and conventional fuel illustrating the source renewal cycle.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define biomass and biofuels and discuss the historical development leading to today's biomass energy technology.

(2) Discuss the nature of the biomass energy resources, including cultivated sources, organic wastes, and animal residues.

(3) Discuss the principal elements of the conversion processes for obtaining biofuels (principally alcohol, methane, and hydrogen) from biomass sources.

(4) Discuss the nature of the converted fuels as compared to fossil and synthetic fuel sources and their transport from generator to end use location.

(5) Discuss the advantages and disadvantages of the biomass conversion process in today's economy.

(6) Discuss the potentials for biomass energy conversion as an alternative energy source.

RATIONALE:

Biomass energy conversion represents one of the most advanced of the solar-chemical technologies. It has potential for distributed applications as well as for large central generating stations. The solar technician should be able to recognize and evaluate the potentials of this technology field.

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UNIT TITLES:

(1) Biomass Energy Technology

(2) Future Potentials

(3) Energy Resources

(4) Energy Conversion

(5) Energy Distribution

(6) Economics

VOCABULARY:

Acid Hydrolysis
Biogas
Batch Digester
Cellulose
Continuous Digester
Digester
Enzyme
Fodder
Garbage
Humus
Incineration
Mash
Manure
Net Productivity
pH
Sewage
Solubilization
Volatile Solids
Acidogeneis
Biofuel
Carbohydrates
Crop Residue
Destructive Distillation
Energy Plantation
Feed Lot
Fixed Solids
Hydrogasification
Hydrolysis
Lignin
Methane
Methanogeneis
Organic Waste
Silviculture
Still
Total Solids
Wood Lot

Reference 1, Chapter 26
Reference 2, pp. 16-20
Reference 3, pp. 255-260
277-279
290-291
Reference 4, pp. 587-628
715-771
1005-1103
Reference 5, pp. 120-124
Reference 6, pp. 154-161
196-219
Reference 7, pp. 346-361

Unit 1. Biomass Energy Technology
- A. Overview of Biomass Technology
    - 1. Definition of biomass
    - 2. Historical development
    - 3. Current applications
- B. Energy Resources
    - 1. Energy crops
    - 2. Organic wastes
    - 3. New plant species
- C. Energy Conversion
    - 1. Direct combustion
    - 2. Thermochemical processes
    - 3. Biochemical processes
- D. Energy Distribution
    - 1. Synthetic fuels
    - 2. Substitute fuels
    - 3. Chemical feedstock
- E. Economics
    - 1. Advantages
    - 2. Disadvantages
    - 3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebooks:

(1) A glossary of the terms set forth in the module vocabulary.

Reference 1, Chapter 25
Reference 4, pp. 1005-1057
Reference 6, pp. 154-161
196-199
208-212
214-218
Reference 7, pp. 346-348

Unit 2. Energy Resources
- A. Terrestrial Plant Species
    - 1. Food crops
    - 2. Non-food crops
    - 3. Crop residue
- B. Forest Species
    - 1. Non-commercial timber
    - 2. Forest residue
    - 3. New plant species
- C. Aquatic Plant Species
    - 1. Algae
    - 2. Fresh-water plants
    - 3. Marine-water plants
- D. Animal Waste
    - 1. Manure (feed lot)
    - 2. Urban sewage
    - 3. Animal carcasses
- E. Organic Waste
    - 1. Garbage
    - 2. Paper
    - 3. Garden debris

STUDENT ACTIVITY

Exercise

Reference 1, Chapter 25

Assignment:

Have students prepare for their course assignment notebook:

(1) A tabulation of representative biomass resources showing generic class, specific biomass species, and energy equivalent.

Reference 1, pp. 25-11 - 25-16
Reference 2, pp. 16-20
Reference 4, pp. 715-756
1005-1103
Reference 5, pp. 120-124
Reference 6, pp. 154-161
196-213
Reference 7, pp. 347-350

Unit 3. Energy Conversion

A. Thermochemical Process - Pyrolysis
   1. Resource and preparation
   2. Conversion process
   3. Products of conversion

B. Thermochemical Process-Liquefaction
   1. Resource and preparation
   2. Conversion process
   3. Products of conversion

C. Thermochemical Process - Gasification
   1. Resource and preparation
   2. Conversion process
   3. Products of conversion

D. Biochemical Process - Anaerobic Digestion
   1. Resource and preparation
   2. Conversion process
   3. Products of conversion

E. Biochemical Process - Fermentation
   1. Resource and preparation
   2. Conversion process
   3. Products of conversion

STUDENT ACTIVITY

Exercise

Reference 6, pp. 159, 196
Reference 7, pp. 349-350

Assignment:

Have students prepare for their course assignment notebook:

(1) A simple flow diagram for each of the five conversion processes discussed showing the nature of the resources, the important conversion parameters (temperature, pressure, etc.), and the products of conversion.

Unit 4. Energy Distribution
- A. Synthetic Crude Oil
  - 1. Crude oil product from biomass
  - 2. Comparison (natural, synthetic, biomass crudes)
  - 3. Biomass crude - from source to market
- B. Substitute Liquids From Biomass
  - 1. Alcohols from biomass
  - 2. Comparison (fossil and biomass resources)
  - 3. Biomass alcohol - from source to market
- C. Synthetic Natural Gas
  - 1. Methane from biomass
  - 2. Comparison (natural, synthetic, biomass gases)
  - 3. Biomass methane - from source to market
- D. Substitute Gases From Biomass
  - 1. Hydrogen
  - 2. Ammonia
  - 3. Other gases (oxygen, carbon dioxide, carbon monoside)
- E. Bioconversion Residuals
  - 1. Char (combustible fuel)
  - 2. Digested sludge (fertilizer)
  - 3. Inorganic solids

STUDENT ACTIVITY

Assignment:

Exercise

Have students prepare for their course assignment notebook:

Reference 2, pg. 18

(1) A histogram comparison of the energy equivalent of natural, synthetic, and substitute products for end use applications.

Reference 1, Chapter 25
Reference 4, pp. 587-592
614-627
715-771
1005-1057
Reference 5, pp. 120-124
Reference 6, pp. 160, 201-202
212-214

Unit 5. Economics
- A. Biomass Pyrolysis Processes
  - 1. Advantages
  - 2. Disadvantages
  - 3. Production costs
- B. Biomass Liquefaction
  - 1. Advantages
  - 2. Disadvantages

3. Production costs

C. Biomass Gasification Processes
   1. Advantages
   2. Disadvantages
   3. Production costs

D. Biomass Anaerobic Digestion Processes
   1. Advantages
   2. Disadvantages
   3. Production costs

E. Biomass Fermentation Processes
   1. Advantages
   2. Disadvantages
   3. Production costs

STUDENT ACTIVITY

Exercise

Reference 1, pp. 25-18, 25-20
Reference 4, pp. 757-771

Assignment:

Have students prepare for their course assignment notebook:

(1) A tabulation of representative biomass conversion processes showing advantages, disadvantages, and production costs.

Reference 1, pp. 25-16, 25-21
Reference 2, pp. 16-20
Reference 3, pp. 259-260 290-291
Reference 4, pp. 715-771 1005-1057
Reference 5, pg. 124
Reference 6, pp. 160, 202 212-213
Reference 7, pp. 347-361

Unit 6. Future Potentials

A. Crude Oil From Biomass
   1. Production factors
   2. Cost factors
   3. Geographical factors

B. Alcohols From Biomass
   1. Production factors
   2. Cost factors
   3. Geographical factors

C. Methane From Biomass
   1. Production factors
   2. Cost factors
   3. Geographical factors

D. Substitute Gases From Biomass
   1. Production factors
   2. Cost factors
   3. Geographical factors

E. New Plant Species
   1. Production factors
   2. Cost factors
   3. Geographical factors

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 2, pg. 20	(1) A summary flow chart of potential biomass resources, conversion technologies, products, and economic sector markets benefited.

MODULE: SOLAR-MECHANICAL ENERGY CONVERSION

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Recognize that solar energy is the primary source responsible for the natural phenomenon of wind and ocean energy and discuss the general characteristics of direct mechanical energy conversion from such sources.

(2) Discuss the elementary principles of mechanical energy storage and its relation to solar energy conversion processes.

(3) Discuss the elementary principles of tidal energy conversion as an alternative energy source.

(4) Discuss the prospects for ocean waves and currents as a possible energy source and the investigations currently in process.

(5) Discuss the elementary principles of non-convective solar ponds and salinity gradients as energy sources.

(6) Discuss the elementary principles of Ocean Thermal Energy Conversion (OTEC) and the future potential for this energy conversion system.

RATIONALE:

Mechanical energy for pumps and rotating shafts can be obtained from the natural forces of wind and water. These natural forces are secondary sources resulting from the interaction of solar energy with the earth's atmosphere, hydrosphere, and dithosphere. They are usually identified as part of the technology of solar energy and hence the solar technician should be knowledgeable of the elementary principles associated with conversion from these sources.

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(1) Stoker, H. Stephen and others, *Energy From Source to Use*, Scott, Foresman and Company, Glenview, Illinois, 1975.

(2) Gibney, Frank (Editor), *Energy: The Fuel of Life*, Bantam/Britannica Books, New York, 1979.

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(4) Kreider, Jan F. and Frank Kreith (Editors), *Solar Energy Handbook*, McGraw-Hill Book Company, New York, 1981.

(5) Application of Solar Technology to Today's Energy Needs, Volume I, Office of Technology Assessment, Congress of the United States, Washington, D.C., June 1978.

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(7) Ruedisili, Lon C. and Morris W. Firebaugh (Editors), Perspectives on Energy: Issues, Ideas, and Environmental Dilemmas, Oxford University Press, New York, 1975.

(8) Priest, Joseph, Energy for a Technological Society: Principles, Problems, Alternatives (Second Edition), Addison-Wesley Publishing Company, Reading, Massachusetts, 1979.

(9) McDaniels, David K., The Sun: Our Future Energy Source, John Wiley and Sons, New York, 1979.

(10) Ocean Energy, Report DOE/CS-0203, U. S. Department of Energy, Technical Information Center, Oak Ridge, Tennessee, November 1980.

(11) Cuff, David J. and William J. Young, The United States Energy Atlas, The Free Press, A Division of MacMillan Publishing Co., New York, 1980.

(12) Shepard, M. L. and Others, Introduction to Energy Technology, Ann Arbor Science Publishers, Ann Arbor, Michigan, 1976.

(13) International Conference on Future Energy Concepts, 30 January - 1 February 1979, Conference Publication No. 171, The Institute of Electrical Engineers, New York, 1979.

(14) Van Dorn, William G., Oceanography and Seamanship, Dodd, Mead and Company, New York, 1974.

UNIT TITLES:

(1) Solar-Mechanical Energy Conversion Technology

(2) Mechanical Energy Storage

(3) Tidal Energy Technology

(4) Ocean Wave/Current Energy Technology

(5) Non-Convective Solar Pond Technology

(6) Ocean Thermal Energy Technology

VOCABULARY:

- Absorption Cycle
- Concentrated Wave Turbine
- Energy Storage
- Generator (Thermodynamic Cycle)
- Hinged Barges
- Head
- Non-convective
- Osmosis
- Ocean Thermal Gradient
- Ocean Current
- Progressive Wave
- Solar Pond
- Solinity Gradient
- Solar-Mechanical Energy
- Tidal Power
- Tidal Basin
- Low Boiling-High Vapor Pressure Fluid
- Compressed Gas
- Condenser
- Elevated Liquid
- Flywheel
- Hydrostatic
- Hydrostatic Head
- Oscillation Wave
- Osmotic Pressure
- OTEC
- Ocean Waves
- Periodic Wave Motion
- Salinity
- Standing Wave
- Tide
- Tidal Range
- Vertical Column Turbine
- Wind Waves

Reference 1, pp. 46-55
262-267
Reference 2, pp. 207-223
Reference 4, pp. 6-1 - 6-4
6-24 - 6-28
Reference 5, pp. 386-387
445-446
466-467

Reference 6, pp. 57-59
430-451
Reference 8, pp. 304-308
Reference 10, pp. 1-4
Reference 12, pp. 118-128

Unit 1. Solar-Mechanical Energy Conversion Technology

- A. Overview of Solar-Mechanical Conversion
  - 1. Definition
  - 1. Kinetic energy to mechanical energy
  - 3. Potential energy to mechanical energy
- B. Energy Resources
  - 1. Direct (wind, water)
  - 2. Indirect (without heat engine)
  - 3. Indirect (with heat engine)
- C. Energy Conversion
  - 1. The energy absorber
  - 2. Mechanical shaft power
  - 3. Efficiency
- D. Energy Distribution
  - 1. Mechanical power
  - 2. Electrical power
  - 3. Mechanical energy storage
- E. Economics
  - 1. Advantages
  - 2. Disadvantages
  - 3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A glossary of the terms set forth in the module vocabulary.

Reference 4, pp. 6-1 - 6-4
6-24 - 6-28
Reference 2, pp. 215, 218
Reference 5, pp. 466-467
Reference 12, pp. 118-128

Unit 2. Mechanical Energy Storage

- A. General Characterization
  - 1. Storage needs and roles
  - 2. Storage modes and applications
  - 3. Characterization parameters
- B. Fly Wheels
  - 1. Definition
  - 2. Characteristics
  - 3. Mechanical elements
- C. Compressed Gases
  - 1. Definition
  - 2. Characteristics
  - 3. Mechanical elements

- D. Elevated Liquids
  - 1. Definition
  - 2. Characteristics
  - 3. Mechanical elements
- E. Economics
  - 1. Advantages
  - 2. Disadvantages
  - 3. Future potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook: (1) Simple flow schematics for conversion systems:
Reference 4, pg. 6-25	a. A flywheel storage component
Reference 4, pp. 6-27 - 6-28	b. A compressed gas storage component
Reference 4, pg. 6-28	c. An elevated liquid storage component.

Reference 1, pp. 262-267
Reference 2, pp. 220-221
Reference 6, pp. 57-59, 134
Reference 7, pp. 359-363
Reference 8, pp. 304-308
Reference 10, pg. 1
Reference 11, pp. 336-337

Unit 3. Tidal Energy Technology

- A. Overview of Tidal Energy Conversion
  - 1. Definition
  - 2. Historical development
  - 3. Current applications
- B. Energy Resources
  - 1. Moon, sun, and tides
  - 2. Tidal range (high tide - low tide)
  - 3. Geographical locations for tidal conversion
- C. Energy Conversion
  - 1. Tidal basin
  - 2. Water turbines
  - 3. Basin filling and emptying
- D. Energy Distribution
  - 1. Power generation
  - 2. Pumped storage
  - 3. Standby (intermittent operation)
- E. Economics
  - 1. Advantages
  - 2. Disadvantages
  - 3. Future potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 1, pg. 264 Reference 8, pg. 305	(1) A simple sketch showing the sun, moon, earth relations during maximum tidal

effects.

Reference 1, pp. 265, 266

(2) A simple sketch showing the operational phases of a tidal power plant as a function of time versus hydrostatic head.

Reference 2, pp. 221-223
Reference 6, pp. 446-451
Reference 10, pp. 1-4
Reference 13, pp. 81-87
100-108
160-163
167-176
390-393
Reference 14, pp. 149-239

Unit 4. Ocean Wave/Current Energy Technology

A. Overview of Wave/Current Conversion
    1. Definition
    2. Historical development
    3. Current applications
B. Energy Resources
    1. Sun, ocean, and wind
    2. Oscillation waves
    3. Surface and vertical ocean currents
C. Energy Conversion
    1. Hinged barges
    2. Vertical column turbine
    3. Concentrated wave turbine
D. Energy Distribution
    1. On board manufacturing processes
    2. Power transmission to shore
    3. Energy storage
E. Economics
    1. Advantages
    2. Disadvantages
    3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) Simple schematic diagrams illustrating the concepts of:

Reference 14, pg. 162
Reference 14, pg. 163
Reference 14, pg. 164

a. Progressive waves
b. Standing waves
c. Periodic wave motion.

Reference 3, pp. 167-183
Reference 4, Chapter 10
Reference 5, pp. 386-387
445-446
Reference 9, pp. 261-265
Reference 10, pp. 1-3

Unit 5. Non-Convective Solar Pond Technology

A. Overview of Non-Convective Solar Pond Conversion
    1. Definition
    2. Historical development
    3. Current applications

B. Energy Resources
   1. Natural solar ponds
   2. Artificial solar ponds
   3. Ocean salinity gradients
C. Energy Conversion
   1. Solar energy collection
   2. Heat extraction
   3. Osmotic-pressure
D. Energy Distribution
   1. Direct mechanical power
   2. Heat engine input
   3. Direct heating
E. Economics
   1. Advantages
   2. Disadvantages
   3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

Reference 9, pg. 263

(1) A schematic comparison of the convecting and non-convecting solar pond principles showing the salt/temperature gradient effects.

Reference 1, pp. 279-282
Reference 2, pp. 223-224
Reference 4, Chapter 19
Reference 9, pp. 231-233
Reference 10, pp. 1-4

Unit 6. Ocean Thermal Energy
A. Overview of Ocean Thermal Energy Conversion
   1. Definition
   2. Historical development
   3. Current applications
B. Energy Resources
   1. Sun, ocean, and thermal gradients
   2. Geographic locations
   3. Low boiling-high vapor pressure fluid
C. Energy Conversion
   1. The ocean thermal cycle
   2. The turbine thermodynamic cycle
   3. Overall thermal efficiency
D. Energy Distribution
   1. Electrical power
   2. Electrolysis (hydrogen and nitrogen)
   3. Aluminum production

E. Economics
  1. Advantages
  2. Disadvantages
  3. Future potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 1, pg. 280	(1) A simple flow diagram of an OTEC power plant operation with indicated temperatures and pressures for the various parts of the thermodynamic cycle.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define wind energy conversion and discuss the historical development leading to today's wind energy technology.

(2) Discuss the nature of the wind energy resource from the solar source, through the atmosphere, to the domestic and local site.

(3) Discuss the principal components of the wind energy converter, including the rotor, shaft, generator, controls, and tower support.

(4) Discuss the distribution of converted wind energy as either mechanical or electrical energy, including storage and power conditioning.

(5) Discuss the advantages and disadvantages of wind energy conversion systems in today's economy.

(6) Discuss the potential for wind energy conversion as an alternative energy source.

RATIONALE:

Wind energy conversion is one of the most advanced of the solar-mechanical technologies. It has potential for distributed applications as well as for central stations. The solar technician should be able to recognize and evaluate the potential of this technology field.

REFERENCES:

(1) Park, Jack, The Wind Power Book, Cheshire Books, Palo Alto, Calif., 1981.

(2) Kreider, Jan F. and Frank Kreith (Editors), Solar Energy Handbook, McGraw-Hill Book Co., New York, 1981.

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UNIT TITLES:

(1) Wind Energy Technology

(2) Energy Resources

(3) Energy Conversion

(4) Energy Distribution

(5) Economics

(6) Future Potentials

VOCABULARY:

Airfoil
Asynchronous Generator
Axial Flow
Bowsprit
Blade Twist (Helix)
Cut-out Speed
Drag
Yaw Axis
Furling Speed
Fantail
Gin Pole
Lolly Axis
Panemone
Pitch
Rated Power
Return Time
Rotor Efficiency
Runaway
Solidity
Synchronous Inverter
Starting Torque
Turbulence
Tangential Flow
Wind Generator
Windmill
Wind Power
Windspeed Profile
Windseeking
Windshaft

Anemometer
Airscrew
Angle of Attack
Blade Tip Speed
Cut-in Speed
Darrieus Rotor
Diametral Flow
Fetch Area
Fans
Gear Ratio
Inverter
Lift
Power Coefficient
Propellers
Rated Speed
Rotor
Reciprocating Pump
Savonius Rotor
Synchronous Generator
Sail
Torque
Torque-speed
Wind Furnace
Wind Machine
Wind Energy
Wind Rose
Windspeed Distribution
Windwheel

Reference 1, pp. 13-49
Reference 2, pg. 23-19
Reference 7, pp. 283-309

Unit 1. Wind Energy Technology

- A. Definition of Wind Energy Conversion
  - 1. The sun and earth's atmosphere (brief)
  - 2. The wind and wind absorber (brief)
  - 3. Mechanical shaft power
- B. Ancient Technology Development
  - 1. The Egyptians and sails
  - 2. The Persians and vertical-shaft windmills
  - 3. The Dutch and horizontal-shaft propeller-type windmills
- C. Colonial Times to the Twentieth Century
  - 1. Development of automatic aiming windmills
  - 2. The American farm windmill
  - 3. Windchargers
- D. Wind Generated Electricity
  - 1. Early French and Russian generators
  - 2. Grandpa's Knob
  - 3. Gedser, Denmark
- E. Current Development Activities
  - 1. Small wind machines
  - 2. Medium wind machines
  - 3. Large wind machines

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A glossary of the terms set forth in the module vocabulary.

Reference 1, pp. 45-65
Reference 2, pp. 23-3 - 23-5
Reference 3, pp. 105-107
Reference 4, pp. 122-124
Reference 5, pp. 430-439
Reference 6, pp. 65-77
Reference 7, pp. 283-291

Unit 2. Energy Resources

- A. Wind Is Kinetic Energy
  - 1. Wind results from sun's heat
  - 2. Power equals kinetic energy per unit time
  - 3. Power proportional to cube of wind velocity
- B. Atmospheric Wind Energy
  - 1. The atmosphere as a heat engine

    2. The major wind systems
    3. Pertubation of the zonal winds
- C. Domestic Wind Energy
    1. U. S. wind patterns - surface level
    2. U. S. wind patterns - 150 foot tower height
    3. Seasonal variations
- D. Site Wind Energy
    1. Average wind speed
    2. Variation and frequency of wind speeds
    3. Topography
- E. Measuring Wind Energy
    1. Anemometer
    2. Windspeed distribution curve
    3. U. S. Weather Bureau data

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 7, pg. 285	(1) A schematic diagram illustrating wind energy conversion.
Reference 1, pp. 64-65	(2) Schematic diagrams illustrating the effect of topography and turbulence.
Reference 7, pg. 292	(3) A tabulation (or histogram) of annual average wind power at 150 feet height for various U. S. regions.

Reference 1, pp. 67-147
Reference 2, pp. 23-6 - 23-19
Reference 3, pp. 23-37
51-62
104-126
Reference 4, pp. 120-131

Unit 3. Energy Conversion
- A. Wind Machine Rotor
    1. Blades (tip speed)
    2. Hub (horizontal or vertical axis)
    3. Balancing
- B. Mechanical Power
    1. Shaft
    2. Torque
    3. Transmission
- C. Electrical Power
    1. Generators
    2. Alternators
    3. Inverters

D. Wind Machine Controls
  1. Tail vanes (yaw control)
  2. Governors (overspeed control)
  3. Shut-off controls

E. Wind Machine Support
  1. Tower (type and bracing)
  2. Tower foundation and axis
  3. Wind machine support frame and bending

STUDENT ACTIVITY

Exercise

Reference 2, pp. 23-12

Assignment:

Have students prepare for their course assignment notebook:

(1) A simple block diagram of a wind energy conversion system indicating major components and flow paths.

Reference 1, pp. 119-147
Reference 2, pp. 23-12 - 23-20
Reference 3, pp. 38-90
Reference 4, pp. 120-131
Reference 7, pp. 282-309

Unit 4. Energy Distribution

A. Wind Power Water Pumping
  1. Reciprocating motion
  2. Centrifugal "water slingers"
  3. Compressed air

B. Water Storage
  1. Ponds and surface tanks
  2. Large volume elevated tanks
  3. Small volume demand accumulators

C. Wind-Electric Systems
  1. DC generator to DC loads
  2. DC generator to AC loads
  3. AC generator to AC loads

D. Electrical Energy Storage
  1. Batteries
  2. Flywheels
  3. Thermal storage

E. Wind Furnaces
  1. Wind driven electric resistance heaters
  2. Wind driven heat pumps
  3. Water storage tank and wind driven paddles

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) Simple schematic diagrams for basic wind-electric systems showing major components of the conversion process. Basic systems should include:

Reference 1, pg. 134

- a. DC generator to DC loads
- b. DC generator, inverter, AC loads
- c. DC generator with AC backup, inverter, AC loads
- d. AC generator with AC backup, AC loads.

Reference 1, pp. 149-155
Reference 2, pp. 23-17 - 23-23
References 3, pp. 127-134
Reference 4, pp. 120-131
References 7, pp. 283-309

Unit 5. Economics

- A. Small Wind Machines, 1-50 kw (Farm, Rural Use)
  - 1. Advantage
  - 2. Disadvantages
  - 3. Cost factors
- B. Medium Wind Machines 100-200 kw (Irrigation, Small Scale Industry, and Utility)
  - 1. Advantages
  - 2. Disadvantages
  - 3. Cost factors
- C. Large Wind Machines, 1-3 MW (Large Private and Public Utilities)
  - 1. Advantages
  - 2. Disadvantages
  - 3. Cost factors
- D. Large Multi-Unit Wind Systems
  - 1. Advantages
  - 2. Disadvantages
  - 3. Cost factors
- E. Legal and Social Aspects
  - 1. Property ownership and wind rights
  - 2. Wind machine owners obligations
  - 3. Social issues

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A tabulation of advantages and disadvantages of wind machines according to the size or rated output of the machine.

Reference 7, pp. 287-309

Unit 6. Future Potentials
- A. Define Wind Energy Regimes and Wind Machine Characteristics
    - 1. High wind energy regime
    - 2. Moderate wind energy regime
    - 3. Low wind energy regime
- B. Land Use
    - 1. High wind energy regime
    - 2. Moderate wind energy regime
    - 3. Low wind energy regime
- C. Wind Energy and U. S. Electrical Generating Requirements
    - 1. Rapid implementation of wind energy systems
    - 2. Medium implementation of wind energy systems
    - 3. Slow implementation of wind energy systems
- D. Economic Factors
    - 1. Economic feasibility and number of machines
    - 2. Fuel prices and break even point
    - 3. Regional wind-electric output
- E. Potential of Wind Machines for Various Applications
    - 1. Electric utility
    - 2. Residential
    - 3. Other (agriculture, remote communities, small industry)

STUDENT ACTIVITY

Exercise

Reference 7, pp. 302-303

Assignment:

Have students prepare for their course assignment notebook:

(1) A tabulation (or histogram) of the number of utility wind generators to reach break even costs in each wind regime (high, moderate, and low).

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define and discuss the elementary principles for the direct conversion of solar energy to electrical energy.

(2) Discuss photoelectrolysis conversion, efficiencies, and potential applications.

(3) Discuss the characteristics of fuel cells and their potential solar-electric conversion applications.

(4) Discuss the elementary principles of thermoelectric conversion and the potential as a solar-electric conversion process.

(5) Discuss the elementary principles of thermionic conversion and the potential as a solar-electric conversion process.

(6) Discuss the proposed concept of using satellites in geosynchronous orbit as a source of electrical power.

RATIONALE:

The direct conversion of solar energy to electrical energy is very important for potential applications throughout our economy. This area of technology has received and is currently receiving considerable attention in both research and applied activities. The solar technician should be knowledgeable of the various potentials available from the direct conversion of solar energy to electrical energy.

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(1) Cheremisinoff, Paul N. and Thomas C. Regino, Principles and Applications of Solar Energy, Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1978.

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(3) Pulfrey, David L., Photovoltaic Power Conversion, Van Nostrand Reinhold Company, New York, 1978.

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(7) Meinel, Aden B. and Marjorie P. Meinel, Applied Solar Energy, Addison-Wesley Publishing Co., Reading, Massachusetts, 1976.

(8) Daniels, Farrington, Direct Use of the Sun's Energy, Ballantine Books, New York, 1977.

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UNIT TITLES:

(1) Solar-Electric Energy Conversion Technology

(2) Photoelectrolysis

(3) Fuel Cell Technology

(4) Thermoelectric Technology

(5) Thermionic Technology

(6) Satellite Solar Power

VOCABULARY:

- Solar-Electric Energy
- Cathode
- Collector
- Thermoelectric
- Photoelectrolysis
- Electrolyte
- Thermocouple
- Microwave
- Electron Emission
- Interelectrode Seeding
- Cesium
- Peltier Effect
- Hot Junction
- Anode
- Emitter
- Photoelectric Effect
- Thermionic
- Electrode
- Thermoelement
- Thermopile
- Geosychronous Orbit
- Interelectrode Space
- Work Function
- Seebeck Coefficient
- Thomson Effect
- Cold Junction

Reference 1, pp. 81-83
141-155
Reference 2, pp. 251-269
Reference 3, pp. 9-65
Reference 5, pp. 393-426
464-483
Reference 6, pp. 20-22
92-113
Reference 7, pp. 526-550
Reference 8, pp. 197-252

Unit 1. Solar-Electric Energy Conversion Technology
- A. Overview of Solar-Electric Conversion
  - 1. Define solar-electric conversion (direct)
  - 2. Brief review of electrical fundamentals
  - 3. Current solar-electric conversion interest
- B. Energy Resources
  - 1. Solar energy (photons and heat)
  - 2. Photosensitive materials
  - 3. Thermo-sensitive materials
- C. Energy Conversion
  - 1. Direct solar to electric (photoelectric effect)
  - 2. Solar cells (brief)
  - 3. Thermo-processes (brief)
- D. Energy Storage
  - 1. Requirements for storage
  - 2. Batteries (brief)
  - 3. Other options (brief)
- E. Energy Distribution
  - 1. Stand-alone applications
  - 2. Local applications (residential)
  - 3. Central power stations

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A glossary of the terms set forth in the module vocabulary.

Unit 2. Photoelectrolysis
- A. Overview of Technology
  - 1. Definition of photoelectrolysis
  - 2. Historical development
  - 3. Current applications
- B. Energy Resources
  - 1. Sunlight
  - 2. Electrodes
  - 3. Electrolyte

- C. Energy Conversion
    - 1. Photoelectrolysis cells
    - 2. Electrochemical photovoltaic cells
    - 3. Efficiency of conversion
- D. Energy Distribution
    - 1. Fuel (hydrogen)
    - 2. Electricity
    - 3. Storage
- E. Economics of Photoelectrolysis Conversion
    - 1. Advantages
    - 2. Disadvantages
    - 3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

Reference 1, pp. 143, 145
Reference 5, pg. 426

(1) A schematic diagram of the photoelectrolysis conversion process showing principal components, flow directions, hydrogen fuel extraction, and electrical energy extraction.

Reference 1, pp. 93-94
153-155
Reference 2, pp. 264-268
Reference 6, pp. 21-22, 117
Reference 8, pp. 242-248
Reference 9, pp. 292-298

Unit 3. Fuel Cell Technology

- A. Overview of Technology
    - 1. Definition of solar-electric fuel cell conversion
    - 2. Compare with non-solar devices
    - 3. Current applications
- B. Energy Resources
    - 1. Light (fuel production)
    - 2. Anode cell fuel
    - 3. Cathode cell fuel
- C. Energy Conversion
    - 1. Brief review of fuel cell conversion process
    - 2. Photocell - fuel cell process
    - 3. Biomass - fuel cell process
- D. Energy Distribution
    - 1. Small capacity electrical power

    2. Large capacity, central power stations
    3. Storage
- E. Economics of Conversion Process
    1. Advantages
    2. Disadvantages
    3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A schematic diagram illustrating the solar-electric energy conversion process using fuel cells. Principal components and slow directions are to be identified.

Reference 2, pp. 257-264
Reference 4, pp. 953, 1193, 1205
Reference 5, pg. 385
Reference 6, pp. 20, 91-92
Reference 7, pp. 9, 31, 545-550
Reference 8, pp. 197-205

Unit 4. Thermoelectric Technology
- A. Overview of Technology
    1. Definition of thermoelectric conversion
    2. Historical development
    3. Current applications
- B. Energy Resources
    1. Solar energy characteristics
    2. Metallic thermoelements
    3. Semiconductor thermoelements
- C. Energy Conversion
    1. Concentrating collectors
    2. Simple thermoelectric loop
    3. The thermopile
- D. Energy Distribution
    1. Electrical energy
    2. Refrigeration
    3. Storage
- E. Economics of Thermoelectric Conversion
    1. Advantages
    2. Disadvantages
    3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

Reference 2, pg. 260
Reference 7, pg. 545

(1) A schematic diagram showing the operation of a simple thermoelectric loop with

external load and all principal components identified.

Reference 2, pp. 251-257
Reference 4, pp. 1193-1205
Reference 5, pp. 383-385
Reference 6, pp. 20-21, 93
Reference 7, pp. 31-31
548-549
Reference 8, pp. 205-206

Unit 5. Thermionic Technology

- A. Overview of Technology
  - 1. Definition of thermionic conversion
  - 2. Historical development
  - 3. Current applications
- B. Energy Resources
  - 1. Heat source
  - 2. Electrodes
  - 3. Interelectrode seeding
- C. Energy Conversion
  - 1. Concentrating collector
  - 2. Electrical energy
  - 3. Efficiency of process
- D. Energy Distribution
  - 1. Electrical energy
  - 2. Thermal energy
  - 3. Storage
- E. Economics of Thermionic Conversion
  - 1. Advantages
  - 2. Disadvantages
  - 3. Future potential

STUDENT ACTIVITY

Exercise

Reference 5, pg. 384
Reference 7, pg. 548

Assignment:

Have students prepare for their course assignment notebook:

(1) A schematic illustrating the principles of solar thermionic conversion with all principal components and flow directions identified.

Reference 1, pp. 95-100
Reference 3, pp. 56-62
Reference 9, pp. 275-276

Unit 6. Satellite Solar Power

- A. Overview of Satellite Solar Power
  - 1. Definition of satellite solar power
  - 2. Historical development of concept
  - 3. Current interest
- B. Energy Resources
  - 1. Extraterrestrial insolation
  - 2. Satellite power station
  - 3. Photovoltaic solar cell arrays

C. Energy Conversion
  1. Energy absorption
  2. DC-microwave conversion
  3. Efficiency of conversion process

D. Energy Distribution
  1. Satellite geosynchronous orbit
  2. Microwave transmission to earth
  3. Earth-based receiving and conversion

E. Economics of Satellite Solar Power
  1. Advantages
  2. Disadvantages
  3. Future potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 9, pg. 276	(1) A schematic illustration of the satellite solar power concept with principal components and flow direction identified.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define photovoltaic energy process and discuss the historical development leading to today's technology.

(2) Describe the photoelectric effect and elementary nature of materials and their properties necessary for photovoltaic applications.

(3) Discuss the photovoltaic conversion process based on the solar cell, modules, and arrays necessary to provide useful power output, and the efficiency of such processes.

(4) Discuss the distribution of electrical energy from the converter including storage, D.C. to A.C. inversion, and power conditioning.

(5) Discuss the advantages and disadvantages of photovoltaic systems in today's economy.

(6) Discuss the potentials of photovoltaic conversion as an alternative energy source.

RATIONALE:

Photovoltaic energy conversion is one of the more advanced solar-electric technologies. It has potential use as a distributed system and therefore a broad range of technician demands are probable. The solar technician should be able to recognize the complexities of the manufacturing process along with opportunities and limitations available in the field.

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(1) Maycock, Paul D. and Edward N. Stirewalt, Photovoltaics: Sunlight to Electricity in One Step, Brick House Publishing Company, Andover, Massachusetts, 1981.

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(3) Dixon, A. E. and J. D. Leslie, Solar Energy Conversion, Pergamon Press, New York, 1979.

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(6) McDaniels, David K., The Sun: Our Future Energy Source, John Wiley and Sons, New York, 1979.

(7) Krauskopf, Konrad B. and Arthur Beiser, The Physical Universe, (Fourth Edition), McGraw-Hill Book Co., New York, 1979.

UNIT TITLES:

(1) Photovoltaic Energy Technology

(2) Energy Resources

(3) Energy Conversion

(4) Energy Distribution

(5) Economics of Photovoltaic Conversion

(6) Future Potentials

VOCABULARY:

Acceptor
Band Gap Energy
Barrier Energy
Depletion Zone
Peak Watt
Photovoltaic Array
Photovoltaic Collector
Photovoltaic System
Thin Film
Boron
Dendrite
Dopant
Hole
P-Silicon
PV
Ribbon
Siemens Process
Photovoltaic-thermal System
Conduction Band
Deep Discharge
Heterojunction
I-V Curve
Minority Carrier
Open Circuit Voltage
Polycrystalline Silicon
Schottky Barrier
Amorphous
Cell Barrier
Cell Junction
Diffusion Length
Photovoltaic
Photovoltaic Cell
Photovoltaic Module
Solar Cell
Valence State
Cadmium
Donor
Gallium
N-Silicon
Phosphorus
Recombination
Semiconductor
Silicon
Wafer
Czochralski Process
Fill Factor
Homojunction
Majority Carrier
Multiple Junction Cell
Short Circuit Current
Power Conditioner

Reference 1, pp. 1-25
169-171
Reference 2, pp. 1-8
Reference 3, pp. 773-778
Reference 5, pp. 24-1 - 24-6
Reference 6, pp. 239-245
Reference 7, pp. 274-287
304-315

Unit 1. Photovoltaic Energy Technology

A. Historical Development
   1. Discovery and selenium photoconductors
   2. Photovoltaic effect connected with a barrier layer
   3. Grown pn junctions and the space program

B. Current Applications
   1. Isolated and remote area applications
   2. Communication systems
   3. Industrial applications and products

C. The Photovoltaic Phenomena
   1. The photoelectric effect
   2. Light generated electric current in wires
   3. Internal charge separation (the barrier)

D. Atoms, Electrons, and Energy Levels
   1. Elementary atomic structure
   2. Energy levels and valence electrons
   3. Covalent bonding between atoms

E. Crystals and Energy Bands
   1. The crystalline state (a periodic space lattice)
   2. Metals and insulators (conduction band, valence band, and band gap)
   3. Intrinsic semiconductor

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A glossary of the terms set forth in the module vocabulary.

Unit 2. Energy Resources

- A. Light, Photons, and Electron Volts
  - 1. Define photon and light relationship
  - 2. Define electron volt and the electromagnetic spectrum in terms of electron volts
  - 3. Briefly describe the energy exchange between photons and electrons
- B. Electrons, Holes and Junctions
  - 1. Describe characteristics of p-type and n-type materials
  - 2. Define the pn junction effect
    - a. Homojunction
    - b. Heterojunction
  - 3. Describe photon generation of electrons and holes
- C. Single Crystal Materials
  - 1. Define single crystal (silicon)
  - 2. Briefly describe growing single crystals
  - 3. Briefly describe doping single crystals
- D. Polycrystalline Materials
  - 1. Define polycrystalline materials
  - 2. Compare single and polycrystalline silicon
  - 3. Identify other potential polycrystals
- E. Thin Film Materials
  - 1. Define thin film materials
  - 2. Briefly describe Schottky barriers
  - 3. Briefly describe MIS and SIS barriers

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:

(1) Schematic diagrams illustrating the photovoltaic principles. Diagrams should include:

Reference 6, pg. 244	a. The ideal single crystal lattice
Reference 6, pg. 247	b. The n-type lattice
	c. The p-type lattice
Reference 6, pg. 248	d. The pn junction.

Reference 1, pp. 32-68
Reference 2, pp. 21-37
Reference 3, pp. 785-841
Reference 4, pp. 395-407
Reference 5, Chapter 24
Reference 6, pp. 245-252

Unit 3. Energy Conversion

- A. Overview of Photovoltaic Conversion Process
  - 1. Direct conversion to electricity
  - 2. Heat generation
  - 3. Sunlight concentration
- B. Photovoltaic Cells
  - 1. Materials and junctions
  - 2. Current and voltage output
  - 3. Efficiency of cells
- C. Photovoltaic Modules
  - 1. Define modules - an assembly of cells
  - 2. Current and voltage factors
  - 3. Size and assembly factors
- D. Photovoltaic Arrays
  - 1. Define array - an assembly of modules
  - 2. Current and voltage factors
  - 3. Size and assembly factors
- E. Concentrators and Photovoltaic Collectors
  - 1. Purpose of concentrators
  - 2. Photovoltaic - concentrator schemes
  - 3. Tracking and heat generation

STUDENT ACTIVITY

Assignment:

Exercise

Have students prepare for their course assignment notebook:

Reference 1, pg. 66

(1) A schematic illustration of the photovoltaic power array showing the assembly by cells into modules, into arrays.

Reference 1, pp. 1-17
63-85
155-161
193-199
Reference 2, pp. 9-12
37-51
Reference 4, pp. 406-407
464-483
Reference 5, Chapter 24

Unit 4. Energy Distribution

- A. Overview of Photovoltaic Energy Distribution
  - 1. Generation to storage
  - 2. Generation and DC distribution
  - 3. Generation and AC distribution
- B. Energy Storage
  - 1. Purpose of energy storage
  - 2. Batteries
  - 3. Flywheel
- C. Power Conditioning
  - 1. Storage charging - discharging
  - 2. Auxiliary power input
  - 3. Photovoltaic power and AC systems
- D. Photovoltaic - Thermal Systems
  - 1. Purpose of photovoltaic-thermal systems
  - 2. Photovoltaic efficiency and temperature
  - 3. Cogeneration-electrical and thermal uses
- E. Small Scale Photovoltaic Devices
  - 1. Define small scale - single cells, modules
  - 2. Examples of small scale photovoltaic devices
  - 3. Brief description of the electric automobile

STUDENT ACTIVITY

Exercise

Reference 1, pg. 67
Reference 2, pp. 11, 39-40
Reference 4, pg. 479

Assignment:

Have students prepare for their course assignment notebook:

(1) A block diagram illustrating the photovoltaic conversion process from sunlight through conversion, power conditioning, storage to load (end use).

Unit 5. Economics of Photovoltaic Conversion

- A. Photovoltaic Economics and the User
    - 1. Initial system costs and monthly payments
    - 2. Alternate fuel cost and photovoltaics
    - 3. Photovoltaics and taxes
- B. Photovoltaic Economics and the Supply
    - 1. Market and product demand
    - 2. Manufacturing and economics
    - 3. Distribution and economics
- C. Photovoltaic Economics and Utilities
    - 1. Utilities' physical position
    - 2. Utilities' economic position
    - 3. Power generation and distribution
- D. Photovoltaic Economics and Government
    - 1. Market growth and government policy
    - 2. Government purchases
    - 3. International markets
- E. Societal Issues
    - 1. Photovoltaics and the environment
    - 2. Photovoltaics and employment
    - 3. Photovoltaics and municipalities

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

Reference 2, pg. 174

(1) A schematic representation of the factors which affect the development of photovoltaic power systems.

Reference 1, pp. 1-17
135-162
179, 184-187
193-199
Reference 2, pp. 197-200
Reference 4, pp. 393-422
Reference 5, pp. 24-24,
24-34

Unit 6. Future Potentials

- A. The Residential/Commercial Sector
  - 1. Residential/Commercial applications
  - 2. Limitations and constraints
  - 3. Integrated energy sources for meeting demand
- B. The Industrial Sector
  - 1. Capital cost factors
  - 2. Photovoltaic manufacturing growth
  - 3. Industrial use and utilities
- C. The Utilities
  - 1. Capital cost factors
  - 2. Fuel costs
  - 3. Societal issues and government policy
- D. Transportation
  - 1. Brief review of historical applications
  - 2. Photovoltaics and the electric car
  - 3. Photovoltaics and aircraft
- E. Factors Influencing Future Potentials
  - 1. Cost reduction goals
  - 2. Technology advancements
  - 3. Credibility of cost and technology goals

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 5, pg. 24-8	(1) A schematic block diagram of a potential system for a building using solar energy both by thermal collection and photovoltaic electricity along with alternative and conventional energy sources.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify and discuss the significance of solar-thermal energy conversion based on output temperature and the elementary principles involved in the conversion processes.

(2) Identify concentrating solar collector types and discuss elementary principles of their use and appropriate applications.

(3) Discuss the elementary principles and optical systems of solar furnaces and the present application of these converters.

(4) Discuss the elementary principles of heat engines, how the solar energy can be introduced into the thermodynamic cycle, and the current applications of solar heat engine technology.

(5) Discuss the applications requiring process heat, how these can be met with solar-thermal energy conversion, and the current applications in process.

(6) Discuss the elementary principles of thermal energy use from shallow solar ponds (convecting) and their current and potential applications.

RATIONALE:

The conversion of solar energy to thermal energy represents the largest potential of the solar energy technology categories. Conversion processes utilize low to high temperatures either directly or indirectly through heat engine conversion to mechanical and electrical energy output. The solar technician should be knowledgeable of the elementary principles involved in the conversion processes and their potentials for future commercialization as alternative energy resources.

REFERENCES:

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(2) Howell, Yvonne and Justin A. Bereny, Engineer's Guide to Solar Energy, Solar Energy Information Services, San Mateo, Calif., 1979.

(3) Kreider, Jan F. and Frank Kreith (Editors), Solar Energy Handbook, McGraw-Hill Book Company, New York, 1981.

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(6) Daniels, Farrington, Direct Use of the Sun's Energy, Ballantine Books, New York, 1974.

(7) Casamajor, A. B. and R. E. Parsons, Design Guide for Shallow Solar Ponds, Report UCRL-52385, University of California, Lawrence Livermore Laboratory, Livermore, California, January 6, 1978.

UNIT TITLES

(1) Solar-Thermal Energy Conversion Technology
(2) Concentrating Collectors
(3) Solar Furnaces
(4) Heat Engines
(5) Process Heat
(6) Shallow Solar Ponds (Convecting)

VOCABULARY:

Concentrating Solar Collector
Concentrator
Parabolic Reflector
Heliostat
Distributed System
Concentration Ratio
Point-focused Receiver
Trough Type Collector
One-axis Tracking
V-trough Reflector
Fresnel Lens
Slat Type Reflector
Boosted Flat Plates
Heat Engine
Brayton Cycle
Working Fluid

Shallow Solar Pond

Aperture
Receiver
Dish Reflector
Central Receiver
Geometric Optics
Solar-thermal Energy
Line-focused Receiver
Tracking
Two-axis Tracking
Side Reflector
Fresnel Reflector
Nontracking
Solar Furnace
Rankine Cycle
Stirling Cycle
Process Heat

Reference 1, pp. 181-183
209-231
Reference 2, pp. 91-116
Reference 3, Chapters 7, 8, and 9
20, 21, 22
Reference 4, pp. 149-166
185-252
1105-1135
1191-1243
Reference 5, pp. 245-389
Reference 6, pp. 37-62
140-147
177-196

Unit 1. Solar-Thermal Energy Conversion Technology

- A. Overview
  - 1. Define solar-thermal energy conversion (insolation on absorber)
  - 2. Define geometric concentration ratio
  - 3. Briefly describe aperture area and receiver area
- B. Nonconcentrating Process
  - 1. Define nonconcentrating process (CR equal to 1)
  - 2. Heat balance (gain less losses)
  - 3. Nominal temperature of thermal output
- C. Intermediate Concentrating Process
  - 1. Define intermediate process (CR less than 20)
  - 2. Characteristics of concentrating process (brief)
  - 3. Nominal temperature of thermal output
- D. High Concentrating Process
  - 1. Define high concentrating process (CR greater than 20)
  - 2. Characteristics of concentrating process (brief)
  - 3. Nominal temperature of thermal output
- E. Distribution of Thermal Energy
  - 1. Direct heating (furnace)
  - 2. Heat exchange (process heat)
  - 3. Heat engines (power generation)

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A glossary of the terms set forth in the module vocabulary.

Reference 1, pp. 219-231
Reference 2, pp. 109-116
Reference 3, Chapters 3, 8, and 9
pp. 7-23 - 7-33
Reference 4, pp. 149-166
185-252
Reference 5, pp. 245-326
Reference 6, pp. 42-57

Unit 2. Concentrating Collectors

- A. Overview of Concentrating Collectors
    - 1. Tubular collectors
    - 2. Concepts of geometric optics
    - 3. Necessity for tracking
- B. Concentrator Geometry
    - 1. V-trough and side reflectors
    - 2. Parabolic and dish reflectors
    - 3. Fresnel lenses and reflectors
- C. Receiver Characteristics
    - 1. Point-focused receiver
    - 2. Line-focused receiver
    - 3. Central receiver
- D. Tracking Systems
    - 1. Nontracking-boosted flat plates
    - 2. One-axis tracking
    - 3. Two-axis tracking
- E. Heat Transfer and Heat Balance
    - 1. Convective transfer (distributed collectors)
    - 2. Central receiver (distributed concentrators)
    - 3. Optical and thermal losses

STUDENT ACTIVITY

Exercise

Reference 3, pg. 9-5

Assignment:

Have students prepare for their course assignment notebook:

(1) A schematic illustration of a Fresnel type concentrator and receiver indicating the sun's position, concentrator aperture, and receiver area for two different time periods.

Reference 1, pp. 68, 220-221
Reference 6, pp. 42-57
140-147

Unit 3. Solar Furnaces

- A. Overview of Solar Furnace Technology
    - 1. Definition of solar furnace
    - 2. Historical review
    - 3. Current applications
- B. The Solar Concentrator
    - 1. Lenses
    - 2. Reflectors

    3. Heliostats and reflectors
- C. The Receiver
    1. Size
    2. Temperature characteristics
    3. Containers and positioning
- D. Energy Distribution
    1. High temperature materials research
    2. Metallurgical operations
    3. Photochemical reactions
- E. Economics
    1. Advantages
    2. Disadvantages
    3. Future potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 6, pg. 45	(1) A simple schematic of the concentration of sunlight onto a receiver as required for solar furnace operation.
Reference 6, pp. 140-147	(2) A compilation of typical solar furnaces currently in operation including the principal elements of their design and operation.

Reference 1, pp. 209-231
Reference 2, pp. 150-153
Reference 3, Chapters 15, 20, 22
Reference 4, pp. 404-411
1105-1136
1191-1243
Reference 5, pp. 327-389
Reference 6, pp. 161-197

Unit 4. Heat Engines

- A. Brief Review of Thermodynamics
    - 1. Carnot efficiency
    - 2. The Rankine cycle (liquid)
    - 3. The Brayton cycle (gas)
- B. Solar-Organic Rankine Cycle
    - 1. Brief description of cycle
    - 2. Working fluid and temperature
    - 3. Current applications
- C. Solar-Steam Rankine Cycle
    - 1. Brief description of cycle
    - 2. Working fluid and temperature
    - 3. Current applications
- D. Solar-Brayton Cycle
    - 1. Brief description of cycle
    - 2. Working fluid and temperature
    - 3. Current applications
- E. Solar-Stirling Cycle
    - 1. Brief description of cycle
    - 2. Working fluid and temperature
    - 3. Current applications

STUDENT ACTIVITY

Exercise

Reference 5, pg. 344
Reference 5, pg. 357
Reference 5, pg. 370

Assignment:

Have students prepare for their course assignment notebook:

(1) Simple schematic diagrams showing principle components and flow direction for:
- a. A solar-Rankine conversion system
- b. A solar-Brayton conversion system
- c. A solar-Stirling conversion system.

Reference 1, pp. 76-77
Reference 3, Chapters 18, 21
Reference 6, pp. 64-74
89-97
119-140

Unit 5. Process Heat

- A. Overview of Solar Process Heat
    - 1. Definition of process heat
    - 2. Low temperature applications
    - 3. Intermediate temperature applications

B. Solar Distillation
    1. Brief description of the process
    2. Solar heat input
    3. Historical (brief) and current applications

C. Solar Food Cooking
    1. Brief description of processes
    2. Solar heat input
    3. Historical (brief) and current applications

D. Solar Crop Drying
    1. Brief description of processes
    2. Solar heat input
    3. Historical (brief) and current applications

E. Solar Industrial Process Heat
    1. Brief description of processes
    2. Solar heat input
    3. Current applications

STUDENT ACTIVITY

Exercise

Reference 3, pp. 21-27
21-28

Reference 3, pp. 21-14
21-33
21-40
Reference 4, pp. 1195-1212
Reference 5, pp. 257-259
Reference 7, complete text

Assignment:

Have students prepare for their course assignment notebook:

(1) A schematic flow diagram illustrating solar process heat for industrial applications with principal components and flow directions identified.

Unit 6. Shallow Solar Ponds (Convecting)

A. Overview of Shallow Solar Ponds
    1. Definition of shallow solar pond
    2. Compare with nonconvecting solar pond
    3. Current applications

B. Solar Energy Collection
    1. Pond location and features
    2. Solar energy absorption
    3. Covers

C. Thermal Storage
  1. Heat gain
  2. Heat loss
  3. Nominal temperatures available

D. Energy Distribution
  1. Heat extraction (batch process)
  2. Heat extraction (flow through)
  3. Storage

E. Economics
  1. Advantages
  2. Disadvantages
  3. Future potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 5, pg. 258	(1) A schematic diagram of a solar pond collector with principal components identified.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define passive solar energy technology and perform simple heat load calculations using degree days.

(2) Discuss the principal design and thermal operation of direct gain passive solar systems.

(3) Discuss the principal design and thermal operation of indirect gain passive solar systems.

(4) Discuss the principal design and thermal operation of isolated gain passive solar systems.

(5) Discuss the various approaches to combining the basic passive systems into a single system including considerations of active systems and non-solar systems.

(6) Discuss the elementary concepts of earth shelters and their relation to and differences with the basic passive solar approaches.

RATIONALE:

Passive techniques have considerable potential for application in the residential and commercial sectors of our economy. These are predominately architectural approaches, and the solar technician must be able to recognize the potentials and the problems for passive approaches. Earth shelters are related to passive approaches, but do exhibit significant differences of which the solar technician must be aware.

REFERENCES:

(1) Mazria, Edward, The Passive Solar Energy Book, Rodale Press, Emmaus, Pennsylvania, 1979.

(2) Howell, Yvonne and Justin A. Bereny, Engineer's Guide to Solar Energy, Solar Energy Information Services, San Mateo, California, 1979.

(3) Colorado State University, Solar Energy Applications Laboratory, Solar Heating and Cooling of Residential Buildings: Sizing, Installation and Operation of Systems (1980 Edition), U. S. Department of Commerce, Washington, D.C., September, 1980.

(4) Kreider, Jan F. and Frank Kreith (Editors), Solar Energy Handbook, McGraw-Hill Book Company, New York, 1981.

(5) McPhillips, Martin (Editor), The Solar Age Resource Book, Everest House, Publishers, New York, 1979.

(6) University of Minnesota, The Underground Space Center, Earth Sheltered Housing Design, Van Nostrand Reinhold Company, New York, 1979.

(7) Application of Solar Technology to Today's Energy Needs, Volume 1, Office of Technology Assessment, Congress of the United States, Washington, D. C., June 1978.

UNIT TITLES:

(1) Passive Solar Energy Technology

(2) Direct Gain Methods

(3) Indirect Gain Methods

(4) Isolated Gain Methods

(5) Combined Methods

(6) Earth Shelters

VOCABULARY:

Atrium
Clerestory
Common Wall
Earth Shelter
Flat Plate Solar Collector
Flat Plate Liquid Collector
Flat Plate Air Collector
Masonry Wall
Passive Solar System
Rock Bin Storage
Storage Charging
Trombe Wall
Ventilation
Water Tank Storage

Adobe
Concrete
Direct Gain
Earth Berm
Greenhouse
Indirect Gain
Isolated Gain
Microclimate
Roof Pond
Skylight
Thermosiphoning
Topography
Vegetation
Water Wall

Reference 1, pp. 13-29
Reference 2, pp. 69-75
155-184
Reference 3, Module 13
Reference 5, pp. 1-5

Unit 1. Passive Solar Energy Technology

- A. Definition of Passive Technology
  - 1. Thermal flow by natural means
  - 2. The building as a collector
  - 3. The building as a storage system
- B. Conduction Heat Loss/Gain
  - 1. Conduction and "R" values
  - 2. "U", the heat transfer coefficient
  - 3. The heat transfer rate
- C. Infiltration Heat Loss/Gain
  - 1. Convection, and air change rates
  - 2. The heat transfer coefficient
  - 3. The heat transfer rate
- D. Floor Heat Loss/Gain
  - 1. Type of building foundation
  - 2. Heat transfer rate for concrete slab on grade
  - 3. Heat transfer rate for other foundations
- E. Design Heat Loss/Gain
  - 1. Define "degree day" and tables by state and station
  - 2. Define heating load per degree day
    - a. Monthly heating load
    - b. Annual heating load
  - 3. Define envelope thermal effectiveness

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 3, pg. 13-9	(1) A schematic drawing of an insulated wall frame with sample calculation of "R" and "U" values.
Reference 3, pp. 13-12, 13-14 (Worksheets HL-1 and HL-2)	(2) A sample building heat load calculation for a simple building envelope. (Instructor to provide sketch of sample building and worksheets for problem).

Reference 1, pp. 29-43
107-109
119-151
226-266
Reference 2, pp. 75-76
85-88
Reference 3, pp. 3-2 - 3-10
Reference 4, Chapter 16
Reference 5, pp. 63-69
Reference 7, pp. 250-251

Unit 2. Direct Gain Methods

A. Overview of Direct Gain
   1. Description of direct gain system
   2. Brief description of distribution and control
   3. Brief description of auxiliary support
      a. Microclimate
      b. Building layout and position

B. Solar Energy Collection
   1. Large areas of glass, south facing
      a. Windows
      b. Clerestories
      c. Skylights
   2. Glass and its solar-optical properties
   3. Solar incidence - summer and winter

C. Energy Storage
   1. Masonry walls
   2. Water walls
   3. The absorber

D. Heat Distribution and Control
   1. Daytime charging of storage
   2. Night heating by convection
   3. Cooling in hot summer climates

E. Auxiliary Heat
   1. Electric lights and appliances
   2. Fireplaces
   3. Body heat

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 1, pg. 30 Reference 3, pp. 3-3, 3-7, and 3-9	(1) Schematic drawings showing the principal characteristics of the direct gain including daytime heat gain and night time convective heating.
Reference 1, pg. 26	(2) A tabulation of heat capacity, specific heat, and density for various materials suitable for thermal storage.
Reference 3, pp. 13-15	(3) A tabulation of the solar optical properties of various glasses according to type and thickness.
Reference 1, pp. 43-58 153-218 Reference 2, pp. 77-84 Reference 3, pp. 3-10 - 3-24 Reference 4, pp. 16-4 - 16-5 16-15 - 16-21 Reference 4, pp. 7-12 21-24	Unit 3. Indirect Gain Methods A. Overview of Indirect Gain 1. Description of indirect gain system 2. Brief description of distribution and control 3. Brief description of auxiliary support B. Solar Energy Collection 1. Large glass areas, south facing 2. Attached greenhouses 3. Roof ponds and exterior water walls C. Energy Storage 1. Masonry thermal walls 2. Interior water walls 3. Exterior water walls and roof pond D. Heat Distribution and Control 1. Daytime heat gain and distribution 2. Nighttime heat distribution 3. Cooling in hot summer climates E. Auxiliary Support 1. Circulating fans 2. Fireplaces, electric lights 3. Collector covers

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:.
Reference 1, pp. 44-51	(1) Schematic diagrams showing the major components of a Trombe wall indirect gain passive system for the day time heat gain, nighttime heating, and hot-climate cooling modes of operation.
Reference 1, pg. 57	(2) Schematic diagrams showing the major components of a roof pond passive system for the daytime heat gain and nighttime heating modes of operation.
Reference 1, pg. 54	(3) Schematic diagrams showing the major components of an attached greenhouse passive system for common wall storage and convective space heating.

Reference 1, pp. 59-65
Reference 2, pp. 84-88
Reference 3, pp. 3-24 - 3-26
Reference 4, pg. 11-3
16-5
16-6
16-21
16-23
Reference 5, pp. 17-20

Unit 4. Isolated Gain Methods
- A. Overview of Isolated Gain
  - 1. Description of isolated gain system
  - 2. Brief description of distribution and control
  - 3. Brief description of auxiliary support
- B. Solar Energy Collection
  - 1. Flat plate liquid collector
  - 2. Flat plate air collector
  - 3. Reflector and cover
- C. Energy Storage
  - 1. Water storage tank
  - 2. Rock storage bin
  - 3. Comparative advantages and disadvantages
- D. Heat Distribution and Control
  - 1. Thermosiphoning hot water
  - 2. Thermosiphoning space heating
  - 3. Cooling in hot summer climates
- E. Auxiliary Support
  - 1. Internal heat generation
  - 2. Ventilation supply
  - 3. Hot air venting

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 2, pg. 85 Reference 3, pg. 3-26	(1) A simple schematic diagram illustrating isolated gain passive solar systems showing the collection, storage, and distribution modes of operation.

Reference 1, Various chapters throughout text
Reference 2, pp. 85-88
Reference 3, Module 3
Reference 4, Chapter 16
Reference 5, pp. 1-16
Reference 7, pp. 250-255

Unit 5. Combined Methods

- A. Building Siting
  - 1. Position of building on property
  - 2. Building orientation
  - 3. Relation to wind and bodies of water
- B. Architecture
  - 1. Building units and topography
  - 2. Buffer units
  - 3. Clustering for solar heat gain
- C. Passive Systems
  - 1. Windows and thermal storage
  - 2. Greenhouse additions
  - 3. Isolated gain systems added
- D. Auxiliary Components and Methods
  - 1. Movable shutters
  - 2. Reflectors
  - 3. Shading devices
- E. Passive System Performance
  - 1. Direct gain - typical heating
  - 2. Indirect gain - typical heating
  - 3. Thermal storage walls

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
	(1) A schematic layout of a passive solar building showing typical:
Reference 7, pg. 252	a. Topography patterns
Reference 1, pg. 81	b. Building orientation characteristics
Reference 1, pg. 91	c. Building buffer spaces.

Reference 6, complete text

Unit 6. Earth Shelters
- A. Site Planning
    - 1. Shelter orientation
    - 2. Site topography and vegetation
    - 3. Soil and groundwater
- B. Architecture
    - 1. Space utilization
    - 2. General design concerns
    - 3. Detailed design concerns
- C. Energy Use
    - 1. Thermal characteristics of earth shelter
    - 2. Energy-efficient design concerns
    - 3. Energy analysis
- D. Structural Design
    - 1. Soil classifications
    - 2. Soil type and structural components
    - 3. Basic structural loads
- E. Waterproofing and Insulation
    - 1. Sources of moisture problems
    - 2. Drainage and damp-proofing
    - 3. Waterproofing and insulation

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
	(1) Typical sketch concepts for earth sheltering, showing the relation of:
Reference 6, pg. 23	a. Shelter and topography
Reference 6, pg. 21	b. Shelter and wind
Reference 6, pp. 44, 45	c. Shelter and sunlight.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define active solar-thermal energy technology and discuss the historical development and current applications for flat plate solar collection systems.

(2) Discuss the basic fundamentals of solar energy collection using flat plate collectors including the functions of the various collector components.

(3) Discuss the significance of energy storage and the various methods available for thermal energy storage.

(4) Discuss the elementary principles involved in using solar energy for heating water and methods for distributing heat from collectors and storage to provide hot water for end uses.

(5) Discuss the elementary principles of space heating using solar systems including direct from collectors, from storage, and with auxiliary heat input.

(6) Discuss the current approaches for solar cooling with active solar energy systems including the elementary principles of the absorption refrigeration cycle.

RATIONALE:

Active solar-thermal energy conversion represents one of the more commercialized areas of solar energy technology. Within this area, there are a number of options for end use, and it is essential that the solar technician be able to recognize the common areas as well as the differences in supplying end use thermal energy.

REFERENCES:

(1) McDaniels, David K., The Sun: Our Future Energy Source, John Wiley and Son, New York, 1979.

(2) Lunde, Peter J., Solar Thermal Engineering, John Wiley and Sons, New York, 1980.

(3) Howell, Yvonne and Justin A. Bereny, Engineer's Guide to Solar Energy, Solar Energy Information Services, San Mateo, California, 1979.

(4) Kreider, Jan F. and Frank Kreith, (Editors), Solar Energy Handbook, McGraw-Hill Book Company, New York, 1981.

(5) Dixon, A. E. and J. D. Leslie (Editors), Solar Energy Conversion, Pergamon Press, New York, 1979.

(6) Duffie, John A. and William A. Beckman, Solar Engineering of Thermal Processes, John Wiley and Sons, New York, 1980.

UNIT TITLES:

(1) Active Solar Energy System Technology
(2) Solar Energy Collection
(3) Energy Storage
(4) Hot Water
(5) Space Heating
(6) Space Cooling

VOCABULARY:

Air Handler
Air Ducts
Absorption Cooling
Active Solar-thermal System
Antifreeze
Differential Thermostat
Drain Down System
Desiccant
Forced Circulation
Hydronics
Hot Water Heater
Heat Loss
Heat Pump
Heat Capacity
Liquid to Air Heat Exchange
Liquid to Liquid Heat Exchange
Pebble Bed
Phase-change Material
Reversible Chemical Reaction
Stratified
Sensible Heat
Thermal Insulation

Absorptivity
Absorber Plate
Adsorption Cooling
Auxiliary Heat
Circulating Pump
Damper
Drain Back System
Emissivity
Glazing
Heat Exchanger
Heat Gain
Heat Transport
Heat Balance
Insulation
Latent Heat
Natural Circulation
Psychrometrics
Reflectivity
Space Heater
Selective Surface
Transmissivity

Reference 1, pp. 163-206
Reference 2, pp. 1-6
387-418
Reference 3, pp. 1-16
91-117
133-153
Reference 4, pp. 1-30 - 1-38
Chapters 11, 12
13, 15
Reference 5, pp. 331-433

Unit 1. Active Solar Energy System Technology

- A. Define Active Solar-Thermal Systems
    - 1. The solar collector - a flat plate
    - 2. A fluid heat transport loop
    - 3. Mechanical means for fluid movement
- B. Development of Active Solar-Thermal Systems
    - 1. Overview of activity since World War II
    - 2. M.I.T. space heating experiments
    - 3. Air heating systems
- C. Hot Water Systems
    - 1. Brief description of purpose
    - 2. Current activities
    - 3. Future potential
- D. Space Heating Systems
    - 1. Brief description of purpose
    - 2. Current activities
    - 3. Future potential
- E. Space Cooling Systems
    - 1. Brief description of purpose
    - 2. Current activities
    - 3. Future potential

STUDENT ACTIVITY

Exercise

Assignment:

Have students prepare for their course assignment notebook:

(1) A glossary of the terms set forth in the module vocabulary.

Reference 1, pp. 133-152
257-259
Reference 2, pp. 120-212
Reference 3, pp. 91-117
Reference 4, Chapter 7
Reference 5, pp. 101-124
149-166
253-286
Reference 6, pp. 144-281

Unit 2. Solar Energy Collection

- A. The Flat Plate Solar Collector
    - 1. Collecting heat
    - 2. Removing heat with a liquid
    - 3. Removing heat with air
- B. The Absorber Plate
    - 1. Absorptivity and emissivity
    - 2. Painted surface
    - 3. Selective surface

- C. Glazing
  - 1. Reflectivity, absorptivity, and transmissivity
  - 2. Glasses
  - 3. Plastic materials
- D. Insulation
  - 1. Thermal conductivity
  - 2. Thermal insulation
  - 3. Gaskets and seals
- E. Heat Balance
  - 1. Heat absorbed
  - 2. Heat loss
  - 3. Collector efficiency

STUDENT ACTIVITY

Exercise

Reference 1, pg. 134
Reference 1, pp. 142, 143

Assignment:

Have students prepare for their course assignment notebook:

(1) A simple schematic illustration of a flat plate solar collector showing:
  - a. Primary components
  - b. Heat balance.

Reference 1, pp. 168-174
Reference 2, pp. 280-310
Reference 3, pp. 119-131
Reference 4, pp. 6-1 - 6-24
12-12 - 12-14
13-10 - 13-11
13-22
15-16 - 15-19
15-26
Reference 6, pp. 326-349

Unit 3. Energy Storage

- A. Thermal Energy Storage
  - 1. Storage purpose and criteria
  - 2. Storage in the collector-distribution loop
  - 3. Heat balance
- B. Sensible Heat Storage Using Water
  - 1. Heat capacity of water
  - 2. Heat input and thermal stratification
  - 3. Heat extraction
- C. Sensible Heat Storage Using Rocks
  - 1. Heat capacity of rocks
  - 2. Heat input and thermal stratification
  - 3. Heat extraction
- D. Storing Heat with Phase-Change Materials
  - 1. Phase-change and latent heat
  - 2. Heat input
  - 3. Heat extraction
- E. Storing Thermal Energy in Chemical Form

1. Reversible chemical reactions and thermal energy
2. Heat input
3. Heat extraction

STUDENT ACTIVITY

Exercise

Reference 1, pp. 170-171
Reference 6, pg. 330

Assignment:

Have students prepare for their course assignment notebook:

(1) A simple flow diagram of a collector to storage loop showing the primary components of the system and the flow directions.

Reference 1, pp. 152-155
Reference 2, pp. 421-440
Reference 3, pp. 133-141
Reference 4, pp. 1-24 - 1-25
11-1 - 11-30
Reference 5, pp. 386-388
Reference 6, pp. 408-430

Unit 4. Hot Water
- A. Solar Hot Water Heater Systems
  1. Identification of solar hot water heaters
  2. Historical development (since WW II)
  3. Current applications
- B. Natural Circulation Systems
  1. Solar heat input
  2. Auxiliary heat
  3. Hot water supply
- C. Forced Circulation Drain Down System
  1. Solar heat input
  2. Auxiliary heat
  3. Hot water supply
- D. Forced Circulation Anti-Freeze System
  1. Solar heat input
  2. Auxiliary heat
  3. Hot water supply
- E. Hot Air Water Heaters
  1. Solar heat input
  2. Auxiliary heat
  3. Hot water supply

STUDENT ACTIVITY
Exercise

Assignment:
Have students prepare for their course assignment notebook:

Reference 6, pg. 409

(1) Simple schematic diagrams showing the collection and distribution, including storage, of solar hot water systems with principal components identified. Schematic diagrams should include:

a. A natural circulation system
b. A forced circulation, drain down system
c. A forced circulation, antifreeze (one-tank) system
d. A forced circulation, antifreeze (two-tank) system.

Reference 1, pp. 163-176
Reference 2, pp. 433-466
Reference 3, pp. 141-144
Reference 4, pp. 1-24 - 1-38
Chapters 12, 13
Reference 5, pp. 331-375
Reference 6, pp. 431-511

Unit 5. Space Heating

A. Solar Space Heating Systems
    1. Identification of solar space heaters
    2. Historical development (since WW II)
    3. Current applications
B. Liquid Heating Systems
    1. Direct heating from collector
    2. The function and use of storage
    3. The auxiliary heat input
C. Liquid to Air Heating Systems
    1. Space heating from the collector
    2. The function and use of storage
    3. The auxiliary heat input
D. Air Heating Systems
    1. Space heating from the collector
    2. The function and use of storage
    3. The auxiliary heat input
E. Combined Space Heat and Hot Water Systems
    1. Drain down collection system
    2. Antifreeze collection system
    3. Air heating system

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook: (1) Simple flow diagrams of combined solar heating and hot water systems showing the major components and flow directions. Diagrams should include:
Reference 2, pg. 434	a. A drain-down liquid system
Reference 2, pg. 436	b. An antifreeze liquid system
Reference 2, pg. 438	c. An air system.
Reference 1, pp. 176-183 Reference 3, pp. 144-153 Reference 4, pp. 6-21 - 6-24 13-19 - 13-20 15-1 - 15-44 Reference 5, pp. 383-433 Reference 6, pp. 457-463 556-587	Unit 6. Space Cooling A. Conditioning Space for Comfort 1. Comfort criteria 2. Psychrometrics 3. The air conditioning process B. Absorption Cooling 1. The absorption cooling cycle 2. Solar heat input 3. Performance and potential C. Adsorption (Desiccant) Cooling 1. The adsorption cooling cycle 2. Solar heat input 3. Performance and potential D. Mechanical Cooling 1. Rankine cycle cooling 2. Solar heat input 3. Potential E. The Heat Pump 1. The heat pump cycles 2. Solar heat input 3. Performance and potential

STUDENT ACTIVITY	Assignment:
Exercise	Have students prepare for their course assignment notebook:
Reference 3, pg. 149	(1) A simple flow diagram of solar absorption cooling showing the principle system components and flow direction.
Reference 6, pg. 566	(2) A simple flow diagram of a combined solar heating, air conditioning, and hot water system showing the principal system components and flow directions.

ENERGY SCIENCE I

Semester Hours Credit: 4
Lecture: 3
Lab: 3

Project Director: Charles G. Orsak, Jr.
Prime Author: Bunny B. Thompson
Contributing Author: James T. Knowles

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INTRODUCTION:

The following outline is an instructor's guide for Energy Science I, a physics based course for solar technology students. The outline has been written to assist the instructor in preparing a class syllabus and lecture notes for this course. The class time assigned to each module is an estimate and adjustments can be made by the instructor depending on the level and qualifications of the class students. References are given as a support to the lecture outline. The curriculum is based on general physics principles geared toward a solar technician's applications. If references listed in this outline are not readily available, most of the information included in this text can be located in a good mathematics and physics textbook. Student activities and laboratories are also included as a guide and must be altered to accommodate the equipment available.

COURSE DESCRIPTION:

Energy Science I is designed as an introduction to the basic scientific principles needed for solar technology. The course begins as a review of algebra, basic mathematics, and an introduction to laboratory operations. The course includes an in depth study of heat transfer and thermodynamics. Gas laws and psychrometric properties of air are also covered in some depth. The course is based on general physics principles, however, the emphasis is placed in the areas of heat, thermodynamic processes, gases as effected by pressure and temperature, and heat transfer fluids used by active solar systems.

OBJECTIVES:

Upon completion of this course the student should:

(1) Be proficient in calculations involving basic algebraic and mathematical principles. This ability should include understanding detailed word problems, the use of technical formulas and logical patterns, and thought processes needed to solve problems.

(2) Understand basic laws of energy and power and use the formulas associated with each.

(3) Have a working knowledge of the fluids used in solar systems including basic fluid mechanics, heat transfer fluids, and refrigerants.

(4) Have a detailed workable knowledge of heat transfer, heat capacity, and thermal energy storage.

(5) Be able to use the gas laws and psychrometric charts to assist in the technology of designing a solar system.

(6) Understand the first and second law of thermodynamics and the principles of heat engines.

(7) Be able to complete the course with the basic physics principles needed to continue further into Energy Science II successfully.

ENERGY SCIENCE I

MODULE INDEX

Title .... Page

Overview of Energy Science........II- 7

Measurement, Pressure and Density........II-11

Energy, Work and Power........II-15

Fluid Mechanics........II-19

Heat and Thermal Energy........II-23

Heat Capacity........II-27

Heat Transfer - Conduction........II-31

Heat Transfer - Convection........II-37

Heat Transfer - Radiation........II-41

Gas Laws........II-45

Psychrometric Properties of Air........II-49

Thermodynamics - First Law........II-55

Thermodynamics - Second Law........II-59

Heat Transfer Fluids, Refrigerants........II-63

MODULE: OVERVIEW OF ENERGY SCIENCE

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Understand and rewrite both large and small numbers in scientific notation.

(2) Solve simple problems involving numbers with exponents.

(3) Understand significant figures as applied to measured quantities.

(4) Solve basic algebraic equations and graphically portray these solutions.

RATIONALE:

This course includes the basic elements of mathematics and physics. A firm understanding of certain basic mathematic principles is a necessity in order to successfully master these principles. This module should be a review of basic skills learned in a previous mathematics course and should reintroduce the student to the techniques of problem solving.

REFERENCES:

(1) General Mathematics Text as used in a prerequisite math course.

(2) Romer, Robert H., Energy, An Introduction to Physics, W.H. Freeman and Co., San Francisco, 1976.

(3) McDaniels, David K., The Sun: Our Future Energy Source, John Wiley and Sons, N.Y. 1979.

UNIT TITLES:

(1) Introduction

(2) Scientific Notation

(3) Significant Figures

(4) Exponential Notation

(5) Algebra

(6) Graphing

VOCABULARY:

Physics
Energy
Mega
Kilo
Deci
Centi
Milli
Ordinate
Abscissa

Reference 1, Chapter 1 Reference 2, Chapter 1	Unit 1. Introduction to Energy as a Science A. Growth of energy usage 1. U.S. 2. World B. Types of energy sources 1. Coal 2. Oil 3. Natural gas 4. Nuclear 5. Hydro-electric 6. Solar C. Definition of energy D. Definition of physics
Reference 1, Chapter 2 Math Book	Unit 2. Scientific Notation A. Powers-of-10 notation B. Prefixes and powers-of-10 notation 1. Mega 2. Kilo 3. Deci 4. Centi 5. Milli 6. Micro
	Unit 3. Significant Figures
	Unit 4. Exponential Notation 1. 1st law of exponents 2. 2nd law of exponents
Math Book	Unit 5. Algebra 1. Solving basic algebraic equations 2. Substitution of numerical values into algebraic equations 3. Finding an unknown value using two algebraic equations
	Unit 6. Graphing 1. Explanation of ordinate and abscissa 2. Graphing of basic algebraic equations on an X and Y axis

OBJECTIVES:

Upon completion of this module, the student should:

(1) Understand the Metric and English systems of units and convert from one system to the other system.

(2) Solve simple problems involving the computation of area and volume of various containers.

(3) Understand the difference between weight and mass.

(4) Know the definitions and formulas for basic physical properties and be able to use the formulas properly.

RATIONALE:

Since measurements, specifications, and designs are often displayed in either English or Metric units, the student needs working knowledge of both systems of units and the ability to convert between these two systems. The student should also be experienced at measuring and calculating specific quantities such as length, area and volumes, the instruments used to measure these quantities, and the units associated with these quantities.

REFERENCES:

(1) Tippens, Paul E., Applied Physics, McGraw-Hill, N.Y., 1978

(2) Dossat, Roy J., Principles of Refrigeration, John Wiley and Sons, N.Y., 1978

(3) Cioffari, Bernard, Experiments in College Physics, D.C. Heath and Co., Lexington, Mass., 1973

UNIT TITLES:

(1) Units and Systems

(2) Conversion of Units

(3) Measurement and Calculation of Length, Area, and Volume

(4) Mass/Weight

(5) Density

(6) Pressure

VOCABULARY:

Mass

Weight

Density

Specific Gravity

Specific Volume

Mass Flow Rate

Volume Flow Rate

Pressure

MODULE: MEASUREMENT, PRESSURE AND DENSITY

Reference 1, Chapter 1	Unit 1. Units and Systems A. English system B. Metric system
Math Book	Unit 2. Conversion of Units A. Conversion of units from metric to English B. Conversion of units from English to metric
	Unit 3. Measurement and Calculation of Length, Area, and Volume A. Square B. Rectangle C. Circle D. Sphere E. Cylinder
Reference 2, Chapter 1	Unit 4. Mass/Weight A. Definition of mass and weight B. Difference between mass and weight on: 1. Earth 2. Moon
	Unit 5. Density A. Definition of density B. Definition of specific volume C. Units for density and specific volume D. Definition of specific gravity and mass and volume flow rates and the use of these equations
	Unit 6. Pressure A. Definition of pressure B. Units used for expressing pressure C. Various methods for determining pressure

STUDENT ACTIVITY

Laboratory Exercise

Assignment:

LAB I:

Part 1: Measure length, width, diameter and height of various small metal cylinders using:
1. Meter Stick
2. Rule
3. Micrometer
4. Vernier Calipers.

Part 2: Calculate area and volume of the metal cylinders in:
1. Metric Units
2. English Units.

LAB II:

Part 1: Using a triple beam balance, weigh the metal samples and determine their mass.

Part 2: For each metal cylinder calculate:
1. Density
2. Specific Volume
3. Specific Gravity.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Comprehend the basic definition and usage of force, velocity, and acceleration.

(2) Understand the relationship between work, power and energy.

(3) Identify the two types of energy, energy efficiency, and energy conversion.

RATIONALE:

Solar energy systems involve the conversion of one form of energy to another form of energy, the ability to do work with this energy, and to utilize power from this system. A full understanding of the concepts of work, power, and energy, is needed to attain the skills of a technician. These skills will enable the technician to not only install and repair solar systems, but also give him/her knowledge of the principles of operation.

REFERENCES:

(1) Harris/Hemmerling, Introductory Applied Physics, McGraw-Hill Co., N.Y., 1980

(2) Tippens, Paul, Applied Physics, McGraw-Hill Co., N.Y., 1978

(3) Croffari, Bernard, Experiments in College Physics, D.C. Heath and Co., Mass., 1973

(4) Harris, Norman C., Experiments in Applied Physics, McGraw-Hill Co., N.Y., 1980

UNIT TITLES:

(1) Force

(2) Motion - Velocity and Acceleration

(3) Work

(4) Power

(5) Energy

VOCABULARY:

Force
Gravity
Weight/Mass
Friction
Equilibrium
Speed
Velocity
Acceleration
Work
ft - lb
N • m
Power
Watt
Horsepower
Energy
Potential Energy
Kinetic Energy

MODULE: ENERGY, WORK AND POWER

Reference 1, Chapter 4 Instructor demonstration - equilibrium of forces using a meter stick, stand, clamps, a set of weights and balance scale.	Unit 1. Force A. Force of gravitation B. Force as a measure of weight, weight-gravity relationship C. Newton's Third Law - Bodies at Rest D. Resultant forces in equilibrium
Reference 2, Chapter 5	Unit 2. Motion: Velocity and Acceleration A. Newton's Second Law of Motion B. Summary of velocity and acceleration
Reference 2, Chapters 7, 8	Unit 3. Work A. Definition of work as a scalar quantity B. Formula for work C. Units for expressing work
Reference 1, Chapter 5	Unit 4. Power A. Definition of power B. Formula for power C. Units for expressing power
	Unit 5. Energy A. General definition of energy B. Kinetic energy C. Potential energy D. Law of conservation of energy
INSTRUCTOR DEMONSTRATION: Reference 3, Experiment 5	LABORATORY ACTIVITIES: Equilibrium of Forces Using a meter stick, stand, clamps, a set of weights and balance scale.
STUDENT LABORATORY: Reference 4, Experiments 5, 9, 10	Simple Machine Coefficient of Friction Acceleration of Gravity Falling

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Know the typical fluids used in solar energy systems and the basic properties of these fluids.

(2) Understand the basic principles of static fluids including pressure, head, and head/energy relationships.

(3) Define and compute the buoyant forces of an object in a fluid as defined by Archimedes' Principle.

(4) Understand flow rates, friction coefficients of pipe and fittings, and calculate pressure drops through a system.

(5) Use Bernoulli's Equation and thoroughly understand the pressure/head relationship.

RATIONALE:

A good understanding of fluids and fluid flow is of vital importance in a solar energy system. Pressure drops and pressure heads are critical to the success of a well designed system and, as a technician or troubleshooter, a firm understanding of the basics of fluid dynamics is a necessity.

REFERENCES:

(1) Howell/Bereny, Engineers Guide to Solar Energy, Solar Energy Information Services, San Mateo, Calif., 1979.

(2) Dossat, Roy J., Principles of Refrigeration, John Wiley & Sons, N.Y., 1978.

(3) Tippens, Paul, Applied Physics, McGraw-Hill Co., N.Y., 1978.

(4) Harris/Hemmerling, Introductory Applied Physics, McGraw-Hill Co., N.Y., 1980.

(5) Harris, Norman C., Experiments in Applied Physics, McGraw-Hill Co., N.Y., 1980.

UNIT TITLES:

(1) Introduction to Fluids
(2) Fluid Pressure
(3) Archimedes' Principle
(4) Fluid Flow
(5) Bernoulli's Equation

VOCABULARY:

Total Pressure (Pt)
Velocity Pressure (Pv)
Static Head (hs)
Pascal's Law
Gauge Pressure
Buoyancy Force
Resistance Flow
Torricelli's Theorem
Static Pressure (Ps)
Total Head (ht)
Velocity Head (hv)
Absolute Pressure
Atmospheric Pressure
Flow Rate
Bernoulli's Equation
Archimedes' Principle

MODULE: FLUID MECHANICS

Reference 1, Chapter 4	Unit 1. Introduction to Fluids A. Types of fluids used in typical solar energy systems 1. Liquid systems 2. Air systems B. Density, specific gravity viscosity of typical fluids used in solar energy systems
Reference 2, Chapter 15	Unit 2. Fluid Pressure A. Total fluid pressure 1. Static pressure - defined 2. Velocity pressure - defined B. Head - pressure relationship 1. Static head - defined 2. Velocity head - defined C. Head - energy relationship D. Measuring fluid pressure
Reference 3, Chapters 15, 16	1. Pascal's Law 2. Absolute pressure - defined 3. Gauge pressure - defined 4. Atmospheric pressure - defined 5. Open tube manometer 6. Barometer
Reference 4, Chapter 11	Unit 3. Archimedes' Principle A. Pressure at any depth B. Downward pressure - weight of object C. Buoyant force - weight of fluid displaced
	Unit 4. Fluid Flow A. Rate of flow or flow rate - defined B. Comparison of flow rate to diameter of pipe
Reference 2, Chapter15, pg. 355	C. Resistance of flow or friction of fluid through various types of pipes and fittings
Reference 4, pp. 218-222	Unit 5. Bernoulli's Equation A. Total head = pressure head + velocity head + friction head
Reference 3, pp. 241-245	B. Pressure/head relationship C. Torricelli's Theorem

STUDENT ACTIVITY

Laboratory Activity I:

Part 1: Students should survey various collector and storage companies to verify the types of fluids used and include:

1. Density of fluids
2. Viscosity of fluid
3. Specific gravity of fluid

Part 2: Students should inspect both liquid and air collectors and compare the friction coefficients of these collectors.

Laboratory Activity II:

Reference 5, Experiment 17

Archimedes' Principle - Buoyancy and Flotation

Part 1: Overview and definition of Archimedes' Principle.

Part 2: Using the following apparatus:

a. Overflow can
b. Catch bucket
c. Heavy liquid, light liquid, water
d. Heavy and light objects
e. Scales or balance beam
f. Graduated cylinder

To determine density of the fluid, weight of the object in air, weight of the object in liquid and verify Archimedes' Principle for submerged bodies.

MODULE: HEAT AND THERMAL ENERGY

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Read various types of thermometers and convert from one scale to another.

(2) Understand the three types of thermal expansion and calculate the coefficient of linear expansion for metals.

(3) Understand the irregular expansion of water.

RATIONALE:

The basic concern of a solar energy technician is heat and temperature within a system. This technician must be able to correctly read and/or convert the temperature to a needed scale. The expansion of various metals and/or joints in a system can be critical. If the technician is familiar with and understands the coefficients of expansion, he/she will more readily be able to identify a problem or leak.

REFERENCES:

(1) Harris/Hemmerling, *Introductory Applied Physics*, McGraw-Hill Co., N.Y., 1980.

(2) Tippens, Paul, *Applied Physics*, McGraw-Hill, N.Y., 1978.

(3) Harris, Norman C., *Experiments in Applied Physics*, McGraw-Hill Co., 1980.

UNIT TITLES:

(1) Thermal Energy
(2) Temperature and Temperature Scales
(3) Temperature Measurement and Conversion
(4) Thermal Expansion
(5) Irregular Expansion of Water

VOCABULARY:

Thermal Energy
Internal Potential Energy
Celsius
Kelvin
Thermal Expansion
Area Expansion
Thermal Equilibrium
Internal Kinetic Energy
Fahrenheit
Rankine
Linear Expansion
Volume Expansion

Reference 2, Chapter 17

Unit 1. Thermal Energy
- A. Thermal energy - defined
- B. Thermal equilibrium - defined
- C. Internal potential energy of a body
- D. Internal kinetic energy of a body

Unit 2. Temperature and Temperature Scales
- A. Celsius scale
- B. Fahrenheit scale
- C. Absolute temperature

Unit 3. Temperature Measurement and Conversion
- A. Thermometry - comparison of thermometer scales
- B. Formulas to convert:
  1. Celsius to fahrenheit
  2. Fahrenheit to celsius
  3. Celsius to Kelvin
  4. Fahrenheit to Rankine

Reference 1, Chapter 13

Unit 4. Thermal Expansion
- A. Linear expansion
  1. Linear expansion - defined
  2. Formula for linear expansion
  3. Coefficient of linear expansion
  4. Example coefficients of linear expansion
  5. Thermal stresses
  6. Differential expansion - bimetallic expansion
- B. Area expansion
  1. Coefficient of area expansion
  2. Comparison of the coefficient of linear expansion and the coefficient of area expansion
- C. Volume expansion
  1. Coefficient of volume expansion
  2. Examples of coefficient of volume expansion for various fluids

Unit 5. Irregular Expansion of Water
- A. Density of water at:
  - 1. 0°C
  - 2. 4°C
  - 3. 10°C
- B. Density/temperature curve for water

STUDENT ACTIVITY

Laboratory Activity I:

Part 1: Students should measure the temperature of various fluids using different types of thermometers.

Part 2: Students should then convert these temperatures from Celsius to Fahrenheit or vice versa, and then to absolute temperature.

Laboratory Activity II:

Reference 5, Experiment 21

Linear Expansion of Metals

Part 1: Overview and introduction to linear expansion of metals and explanation of the formula to calculate the coefficient of linear expansion.

Part 2: Using a linear expansion apparatus, an electric buzzer or light, test rods of various metal and a steam generator. Students can calculate the coefficient of linear expansion for each metal during heating.

MODULE: HEAT CAPACITY

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define the states of matter, heat, specific heat, and the change of phase relationships.

(2) Understand the units of heat, the difference between heat and temperature, and convert between the units of heat.

(3) Define and calculate specific heat both mathematically and experimentally.

(4) Define and calculate the latent heat of fusion and the latent heat of vaporization both mathematically and experimentally.

RATIONALE:

Since heat is the primary function of most solar energy systems, an in-depth study of heat and thermodynamics should be included in this curriculum. The student should understand the principles of specific heat of various liquids and metals, preferably those liquids and metals most used in solar systems. Latent heat of vaporization is of primary importance since steam and/or pressure can be detrimental to the success of certain systems and of primary importance to the success of other types.

REFERENCES:

(1) Tippens, Paul, Applied Physics, McGraw-Hill Co., N.Y., 1978.

(2) Dossat, Roy J., Principles of Refrigeration, John Wiley and Sons, N.Y., 1978.

(3) Cioffari, Bernard, Experiments in College Physics, D.C. Heath and Co., Lexington, Mass., 1973.

(4) Harris, Norman C., Experiments in Applied Physics, McGraw-Hill Co., N.Y., 1980.

UNIT TITLES:

(1) States of Matter
(2) The Quantity of Heat
(3) Specific Heat Capacity
(4) Change of Phase

VOCABULARY:

Heat
Kilocalorie
Specific Heat Capacity
Latent Heat of Fusion
Melting Point
Calorie
Btu
Joule
Fusion
Latent Heat of Vaporization

Reference 2, Chapter 2

Unit 1. States of Matter
- A. Solid
- B. Liquid
- C. Gas
- D. Internal potential energy defined for each state

Unit 2. The Quantity of Heat
- A. Heat - defined
- B. Units of heat measurement
  - 1. Calorie (cal)
  - 2. Kilocalorie (kcal)
  - 3. British thermal unit (Btu)
  - 4. Joule (J)
- C. Conversion of heat units i.e., calories to Btu; Btu to joules
- D. Distinction between heat and temperature
- E. Examples of the rise in temperature of different masses when equal amounts of heat are applied

Reference 1, Chapter 18

Unit 3. Specific Heat Capacity
- A. Heat capacity - definition and formula
- B. Specific heat capacity
  - 1. Definition
  - 2. Formula
  - 3. Units
  - 4. Examples for various substances

Unit 4. Change of Phase
- A. Example (drawings) of the molecular separations and movement in the solid, liquid, and gas phases.
- B. Latent heat of fusion
  - 1. Definition
  - 2. Formula
- C. Latent heat of vaporization
  - 1. Definition
  - 2. Formula
- D. Examples of latent heat of fusion and vaporization for various substances

STUDENT ACTIVITY

Laboratory Activity I:

Using one large flask of water and one smaller flask of water (i.e., two different masses) and two identical hot plates or burners, measure the rise in temperature of each when identical amounts of heat are applied.

Laboratory Activity II:
Specific Heat

Reference 3, pg. 101,
Experiment 22

Part 1: Using a calorimeter, burner thermometers and test liquids, determine the specific heat of the liquid.

Reference 4, pg. 119,
Experiment 24

Part 2: Using the equipment listed above, determine the specific heat of metallic solid specimen, such as lead, aluminum, copper, steel, etc.

Laboratory Activity III:

Reference 3, pg. 105,
Experiment 23

Change of State - Heat of Fusion - Heat of Vaporization

Part 1: Using a calorimeter, triple beam balance, thermometers, and ice, determine the latent heat of fusion for water.

Reference 4, pg. 123,
Experiment 25

Part 2: Using a calorimeter, steam generator, triple beam balance, thermometers and water, determine the latent heat of vaporization for water.

MODULE: HEAT TRANSFER - CONDUCTION

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define the three modes of heat transfer and understand the concept of thermal equilibrium.

(2) Understand the formulas for and the relationship between conductivity, resistance (R-factor) and overall heat transfer coefficient (U-factor).

(3) Understand and calculate degree days.

(4) Calculate the design loss, space heating load, and domestic heat load for a very simple room structure.

RATIONALE:

Heat transfer by conduction is of primary importance, especially in a flat plate solar system. Conductivity, R-factor and U-factor are necessities in understanding the heating loads needed in a home or business. It is necessary to calculate these loads first in order to properly size a solar system.

REFERENCES:

(1) Harris/Hemmerling, *Introductory Applied Physics*, McGraw-Hill Co., 1980.

(2) Tippens, Paul, *Applied Physics*, McGraw-Hill, 1978.

(3) Cromer, Alan, *Physics in Science and Industry*, McGraw-Hill Co., N.Y., 1980.

(4) U.S. Department of Energy, Solar Heating and Cooling of Residential Buildings: *Sizing, Installation and Operation of Systems*, Colorado State University, 1980.

(5) Howell/Bereny, *Engineers Guide to Solar Energy*, Solar Energy Information Services, San Mateo, Calif., 1979.

(6) Mazria, Edward, *The Passive Solar Energy Book*, Rodale Press, Emmaus, Pa., 1979.

(7) Harris, Norman C., *Experiments in Applied Physics*, McGraw-Hill Co., N.Y., 1980.

MODULE: HEAT TRANSFER - CONDUCTION

UNIT TITLES:

(1) Heat Transfer - An Introduction
(2) Thermal Energy and Thermal Equilibrium
(3) Thermal Conductivity
(4) The R-Factor (Resistance Factor)
(5) The U-Factor (Overall Heat Transfer Coefficient)
(6) Degree Days
(7) Total Heating Loads

VOCABULARY:

Heat Transfer
Convection
Thermal Equilibrium
R-Factor
Degree Days
Heating Loads
Design Heating Loads
Domestic Hot Water Heating Loads
Conduction
Radiation
Thermal Conductivity
U-Factor
Design Heating Load
Design Temperature Difference
Space Heating Loads

MODULE: HEAT TRANSFER - CONDUCTION

Reference 1, Chapter 13	Unit 1. Heat Transfer - An Introduction A. Heat transfer - definition B. Three methods of heat transfer
Reference 2, Chapters 17, 19	Unit 2. Thermal Energy and Thermal Equilibrium A. Total internal energy of an object B. Transfer of energy from one object to another C. Thermal equilibrium - definition
	Unit 3. Thermal Conductivity A. Conduction - definition B. Thermal conductivity (k) 1. Definition 2. Examples of thermal conductivity (k) for various types of materials C. Heat transfer equation using thermal conductivity
Reference 3, Chapter 9 Reference 4, Module 13	Unit 4. The R-Factor (Resistance Factor) A. Definition of resistance of a material to heat conductance (R-Factor) B. Formula used to relate R-Factor and thermal conductivity C. Examples of R-Factor for various common materials D. Calculating the total resistance (R_T) for a wall with more than one layer of materials
	Unit 5. The U-Factor (Overall Heat Transfer Coefficient) A. Definition of U-Factor B. Formula used to determine U-Factor C. Examples of U-Factor for various common wall structures
Reference 5, Chapter 8	Unit 6. Degree Days A. Definition B. Formula for determining number of degree days

- C. Tabulated values of degree days in most U.S. cities (government print or Climatic Atlas of the U.S.)

Unit 7. Total Heating Loads

- A. Design heating loss
  - 1. Definition
  - 2. Sample heat loss calculations
  - 3. Infiltration loss - definition
- B. Design temperature difference
  - 1. Definition
  - 2. Examples for outdoor design temperatures for various locations
- C. Average space heating load
  - 1. Defined
  - 2. Formula to determine average monthly/yearly heating load
- D. Domestic hot water heating load
  - 1. Averages as given by government based on four member family including:
    - a. average number of gallons used
    - b. average temperature of water
    - c. average temperature difference

STUDENT ACTIVITY

Reference 6, Chapter III

Laboratory Activity I:

Part 1: Students are shown several wall configurations. Using these walls, the student is to:

1. Show a tabulated value of the thermal conductivity for each material
2. Calculate R_T
3. Calculate U.

Part 2: Students are given either a hypothetical or actual room with windows, doors and specified wall structure. Students then calculate:

1. Design heating loss
2. Design heating load for various given conditions.

Reference 7, Experiment 26

Laboratory Activity II:

Heat Transfer - Conductivity of Copper
Using a Searles heat conductivity apparatus, a steam generator, thermometers, and a copper rod, determine the conductivity of the copper rod.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Define and illustrate natural and forced convection.

(2) Understand the concept of solar use in the masonry thermal storage well, Trombe wall, and greenhouse.

(3) Understand the passive use of solar energy in the convection loop system and the thermosiphoning system.

RATIONALE:

As passive solar energy becomes more and more popular, the concepts of convective heat transfer becomes increasingly important. The student should be well versed in many areas and include systems other than active solar systems to his knowledge. The systems and building options using convective air or water flow should be a part of this knowledge as well as the design and use of greenhouses.

REFERENCES:

(1) Tippens, Paul, Applied Physics, McGraw-Hill, 1978.

(2) Dossat, Roy J., Principles of Refrigeration, John Wiley and Sons, N.Y., 1978.

(3) Mazria, Edward, The Passive Solar Energy Book, Rodale Press, Emmaus, Pa., 1979.

(4) Howell/Bereny, Engineers Guide to Solar Energy, Solar Energy Information Services, San Mateo, Calif., 1979.

UNIT TITLES:

(1) Convection
(2) Passive Solar Energy
(3) Natural Convection
(4) Forced Convection
(5) Convective Loop Storage
(6) Thermosiphoning
(7) Convective Heat Losses

VOCABULARY:

Convection
Natural Convection
Masonry Thermal Wall Storage
Convective Loop Storage
Passive Solar Energy
Forced Convection
Trombe Wall
Thermosiphoning

Reference 1, Chapter 19

Unit 1. Convection
  - A. Definition
  - B. Graphic illustration of convective current

Unit 2. Passive Solar Energy
  - A. Definition
  - B. Short history
  - C. Most common uses of passive solar energy
  - D. Design concepts of passive solar energy
  - E. Examples of the use of passive solar energy, i.e., specific houses using passive solar energy

Reference 2, Chapter 2

Unit 3. Natural Convection
  - A. Definition
  - B. Path of natural convection - warm air/water replacing cooler air/water

Reference 3, Chapter III

  - C. Examples of the use of natural convection including graphic illustrations
    1. Masonry thermal storage wall
    2. Trombe wall
    3. Greenhouse
    4. Water thermal storage wall

Unit 4. Forced Convection
  - A. Definition
  - B. Examples of the use of forced convection including graphic illustrations
    1. Trombe wall with forced air circulation
    2. Greenhouse with forced air circulation

Reference 4, Chapter 3

Unit 5. Convective Loop Storage System
  - A. Definition
  - B. Drawings, graphic or engineering specs to illustrate this system

Unit 6. Thermosiphoning
  A. Definition
  B. Thermosiphoning water heater
  C. Thermosiphoning space heater

Unit 7. Convective Heat Losses
  A. Illustration of convective heat losses from cover plate of a collector
  B. Percentage of heat losses due to convection on a collector

STUDENT ACTIVITY

Laboratory Activity I:

Given a specific design of a house and location the student should plan the best use of the house and lot to minimize energy costs using passive solar energy. Students can include:

1. A masonry thermal storage wall
2. Large thermal windows
3. Greenhouse
4. Trombe wall
5. Trees

Laboratory Activity II:

Given an active and working flat plate or concentrating collector and thermometers, have the students measure the temperature on the cover plate:

1. With no air movement across the plate
2. With various wind speeds (forced) across the cover plate.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Understand the concept of electromagnetic and thermal radiation.

(2) Be familiar with the term blackbody as an "ideal" radiator and emissivity as a measure of the "real" radiation.

(3) Calculate the net rate of radiation from various points on a solar collector.

RATIONALE:

Radiation is a substantial factor in the heat losses and, consequently, the efficiency of a collector. In order to evaluate a collector, some knowledge of radiation losses and good emissivity of the product must be used. The ability to understand and calculate the net rate of radiation from a collector could prove invaluable in correcting or troubleshooting a system in trouble. A workable knowledge of emissivity is especially valuable when comparing selective surface absorber versus a nonselective surface.

REFERENCES:

(1) Tippens, Paul, Applied Physics, McGraw-Hill, N.Y., 1978.

(2) McDaniels, David K., The Sun, John Wiley and Sons, N.Y., 1979.

UNIT TITLES:

(1) Thermal Radiation
(2) Blackbody Radiation
(3) Emissivity
(4) Stephan-Boltzman Law
(5) Net Rate of Radiation

VOCABULARY:

Electromagnetic Waves
Absolute Temperature
Emissivity
Stephan - Boltzman Constant
Thermal Radiation
Blackbody Radiation
Stephan - Boltzman Law
Net Rate of Radiation

Reference 1, Chapter 19

Reference 2, Chapters 6, 7

Unit 1. Thermal Radiation
- A. Electromagnetic waves - definition
- B. Thermal radiation - definition
- C. Rate of thermal energy radiation varies with fourth power of the absolute temperature

Unit 2. Blackbody Radiation
- A. Definition or concept
- B. Examples of good radiation versus poor radiators
- C. Concept of blackbody as "ideal"

Unit 3. Emissivity (e)
- A. Definition
- B. Unitless quantity between 1 and 0
  - 1. For a blackbody, $e = 1$
  - 2. For a highly polished silver surface, $e = 0$
- C. Examples of specific materials and their emissivity at specific temperatures

Unit 4. Stephan - Boltzman Law
- A. Rate of radiation (R)
  - 1. Definition
  - 2. Formula for calculating $R = e \theta T^4$
  - 3. Definition of θ as a proportionality consultant $\theta = 5.67 \times 10^{-8} w/m^2 xK^4$
- B. Example problems involving
  - 1. Radiation from cover plate of collector
  - 2. Radiation from absorber plate of a flat plate collector
  - 3. Radiation from the absorber tube of a concentrating collector

Unit 5. Net Rate of Radiation
- A. Definition
- B. Formula, $R = e \theta (T_1^4 - T_2^4)$
- C. Graphic illustrator of net rate of radiation
- D. Actual calculations using a collector

STUDENT ACTIVITY

Laboratory Activity I:

Using an actual flat plate or concentrating collector, engineering specifications and thermometers, have the students:

1. Read the engineering specs to determine emissivity
2. Calculate R under working conditions on:
    a) The cover plate
    b) Absorber plate
    c) Back of the collector
    d) Sides of the collector.

MODULE: GAS LAWS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Understand the characteristics of gases and the basic relationships between pressure, volume, and temperature.

(2) Utilize the general or ideal gas law in both formula and diagrammatic methods.

(3) Thoroughly understand the concept and graphics of a P-V diagram and triple point phase diagram.

RATIONALE:

Since various types of solar systems utilize pressurized gases, a good working knowledge of gases and gas laws is necessary to the student's background.

REFERENCES:

(1) Dossat, Roy J., Principles of Refrigeration, John Wiley and Sons, N.Y., 1978.

(2) Tippens, Paul, Applied Physics, McGraw-Hill Co., N.Y., 1978.

(3) Croffari, Bernard, Experiments in College Physics, D.C. Heath and Co., 1973.

UNIT TITLES:

(1) Characteristics of Gases

(2) Ideal Gases

(3) Pressure - Volume Relationship

(4) Volume - Temperature Relationship

(5) Pressure - Temperature Relationship

(6) General/Ideal Gas Law

(7) Liquifaction of a Gas

(8) Vaporization

VOCABULARY:

Absolute Temperature

Isochronic Process

Boyle's Law

Critical Temperature

Liquifaction

Evaporation

Sublimation

Condensation

Isothermal Process

Ideal Gases

Charles' Law

Universal Gas Constant

Vaporization

Boiling

Saturated Vapor Pressure

Triple Point

Reference 1, Chapter 3

Unit 1. Characteristics of Gases
- A. Velocity and movement of molecules
- B. Molecular separations in a gas
- C. Expansion of solids and liquids
- D. Review of absolute temperature
  - 1. Conversion °F to °R
  - 2. Conversion °C to °K

Unit 2. Ideal Gases
- A. Molecular collision relationship
- B. Idea of "perfect" gas behavior

Unit 3. Pressure Volume Relationship
- A. Robert Boyle - short history
- B. Isothermal process - definition
- C. Boyle's Law
  - 1. Explanation of written law
  - 2. Formula for Boyles Law
- D. Pressure-Volume graph i.e., P-V diagram
- E. Graphic or drawn illustration of a gas compressed or expanded under a constant temperature

Reference 2, Chapter 20

Unit 4. Volume - Temperature Relationship
- A. Jacque Charles - short history
- B. Charles' Law
  - 1. Explanation of written law
  - 2. Formula for Charles' Law
- C. Graphic or drawn illustration of a constant temperature process during compression or expansion

Unit 5. Pressure - Temperature Relationship
- A. Isochronic process - definition
- B. Explanation of written law
- C. Formula for pressure - temperature relationship
- D. Graphic or drawn illustration during a constant volume process

Unit 6. General/Ideal Gas Law
  A. Combination of Boyle's and Charles' Law
  B. Universal gas constant (R)
  C. General or Ideal Gas Law
    1. Formula
    2. Detailed explanation of each term in formula

Unit 7. Liquifaction of a Gas
  A. Behavior of intermolecular forces
  B. Critical temperature - definition
  C. P - V diagram showing liquifaction of a gas

Unit 8. Vaporization
  A. Liquid to vapor phase occurs by:
    1. Evaporation
    2. Boiling
    3. Sublimation
  B. Saturated vapor pressure - definition
  C. Triple point phase diagram

STUDENT ACTIVITY

Laboratory Activity I:

General Gas Law

Part 1: Using a calibrated thermistor and ordinary household pressure cooker heat the air inside the cooker.

Part 2: Find the relationship between pressure and temperature when the volume and mass remain constant.

Laboratory Activity II:

Charles' Law of Gases

Reference 3, pg. 109,
Experiment 24

Part 1: Using a Charles' Law apparatus, (capillary tube with mercury thread) boiling water, ice, and thermometers find the relationship between volume and temperature.

Part 2: Record the volume of air in the capillary tube under various temperature conditions. Plot a graph of volume vs temperature.

MODULE: PSYCHROMETRIC PROPERTIES OF AIR

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Understand the composition of air and water vapor, and the partial pressures exerted by these.

(2) Calculate and use the basic terms of psychrometrics.

(3) Utilize a psychrometric chart and readily determine each of the psychrometric terms.

(4) Understand the heating and cooling processes and define and illustrate solar applications.

RATIONALE:

In the design and application of solar systems to heat or cool, the conditions of the air being heated or cooled is of primary importance. The psychrometric properties of air and water vapor can have a very definite effect on the design, size, or application of a solar system.

REFERENCES:

(1) Dossat, Roy J., Principles of Refrigeration, John Wiley and Sons, N.Y., 1978.

(2) System Design Manual, Part 2, Air Conditioning, Carrier Air Conditioning Co., N.Y., 1974.

(3) GTA - 3A Advanced General Training, Air Properties and Measurements, Carrier Air Conditioning Co., N.Y., 1978.

UNIT TITLES:

(1) Composition of Air

(2) Dalton's Law of Partial Pressure

(3) Psychrometric Terms

(4) Psychrometric Charts

(5) Psychrometric Processes - Air Mixtures

(6) Psychrometric Processes - Sensible Heating

(7) Psychrometric Processes - Sensible Cooling

VOCABULARY:

Dry Air
Water Vapor
Barometric Pressure
Dew Point Temperature
Absolute Humidity
Humidity Ratio
Wet Bulb Temperature
Enthalpy
Sensible Heating
Sensible Cooling
Evaporative Coolers
Air on Moist
Partial Pressure
Psychrometrics
Humidity
Relative Humidity
Saturation Ratio
Dry Bulb Temperature
Air Mixture
Coil Bypass Factor
Dehumidification

MODULE: PSYCHROMETRIC PROPERTIES OF AIR

Reference 1, Chapter 5

Unit 1. Composition of Air
- A. Composition of dry air
- B. Amount of water vapor in air

Reference 2, Part 2

Unit 2. Dalton's Law of Partial Pressures
- A. Partial pressure exerted by each gas
- B. Total pressure: sum of the partial pressures

Reference 3

- C. Total Barometric pressure: sum of:
  - 1. Partial pressure exerted by dry gases
  - 2. Partial pressure exerted by water vapor

Unit 3. Psychrometric Terms
- A. Dew Point Temperature - the temperature at which the water vapor in the air is saturated
- B. Humidity - water vapor in the air
- C. Absolute Humidity - mass of water vapor per unit volume of air
- D. Relative Humidity - ratio of actual partial pressure exerted by water vapor to partial pressure of water vapor if air was saturated
- E. Humidity Ratio - mass of water vapor per unit mass of dry air
- F. Saturation Ratio - ratio of the actual humidity ratio to the humidity ratio of saturation for the same temperature
- G. Wet Bulb Temperature - temperature as measured by a wet bulb thermometer. A relationship between dry bulb temperature and dew point
- H. Dry Bulb Temperature - temperature as measured by an ordinary thermometer
- I. Enthalpy - "total heat" (h)

Unit 4. Psychrometric Charts
- A. Steam tables
  - 1. Copies to each student
  - 2. Instruction in locating
    - a. Temperature
    - b. Pressure
    - c. Specific volume
    - D. dew point temperature
    - e. Saturation pressure
    - f. Partial pressure exerted by water vapor
    - g. Enthalpy
- B. Psychrometric Chart
  - 1. Copies to each student
  - 2. Instruction in locating
    - a. Humidity ratio
    - b. Dew point temperature
    - c. Specific volume
    - d. Relative humidity
    - e. Dry bulb temperature
    - f. Enthalpy
- C. Interpolation of steam table and psychrometric charts

Unit 5. Psychrometric Processes - Air Mixtures
- A. Mixing adiabatically, enthalpy of the mixture is the sum of the two individual enthalpies
- B. Dew point temperature of the mixture

$$Tc = \frac{(Ma)(Ta) + (Mb)(Tb)}{Mc}$$

where (Ma) & (Ta) are mass and temperature of airstream (a), (Mb) & (Tb) are mass and temperature of airstream (b), (Mc) & (Tc) are mass and temperature of the mixture of (a) & (b)

Unit 6. Psychrometric Processes - Sensible Heating
- A. Definition
- B. Sensible heating process example - shown on a psychrometric chart
- C. Coil bypass factor
  - 1. Definition
  - 2. Formula

Unit 7. Psychrometric Processes - Sensible Cooling
- A. Definition
- B. Dehumidification
- C. Evaporative coolers
  - 1. Definition
  - 2. Engineering specs as an example
  - 3. Solar application

STUDENT ACTIVITY

__Laboratory Activity__:

Part 1: Give students a sample house in a dry climate, such as Arizona. Include square footage and specific temperature and air mixture conditions.

Part 2: Students should design a very simple evaporative cooling system with a solar dehydrator. Students will be required to include:

1. Specific system
2. Engineering specs
3. Basic drawings.

__Laboratory Activity II__:

Sling Psychrometer

Part 1: Using a common sling thermometer and ordinary thermometer, have the students determine the dry bulb and wet bulb temperature inside the lab and outside the building.

Part 2: Using this information, students should be able to find the dew point temperature (if barometric pressure is known) and the relative humidity.

MODULE: THERMODYNAMICS - FIRST LAW

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Understand the concept of thermodynamic equilibrium and thermodynamic processes.

(2) Calculate the mechanical equivalent of heat and convert from metric units to engineering units and vice versa.

(3) Understand and define the first law of thermodynamics and represent the first law on a P-V diagram.

(4) Define and illustrate adiabatic, isochoric, and isothermal processes.

RATIONALE:

The first law of thermodynamics is the foundation for ultimately understanding and utilizing heat, work, and energy. To eventually work with air conditioning or heating processes, as applied by solar or otherwise, the basics of thermodynamics must be covered.

REFERENCES:

(1) Harris/Hemmerling, Introductory Applied Physics, McGraw-Hill Co., N.Y., 1980.

(2) Tippens, Paul, Applied Physics, McGraw-Hill Co., 1978.

UNIT TITLES:

(1) Thermodynamics
(2) Mechanical Equivalent of Heat
(3) Law of Conservation of Energy
(4) First Law of Thermodynamics
(5) Adiabatic Processes
(6) Isochoric Processes
(7) Isothermal Processes

VOCABULARY:

Thermodynamics
Energy
Joule's Constant
Law of Conservation of Energy
P-V Diagram
Isochoric Processes
Heat
Thermodynamic Equilibrium
Mechanical Equivalent of Heat
First Law of Thermodynamics
Adiabatic Processes
Isothermal Processes

Reference 1, Chapter 16

Unit 1. Thermodynamics
- A. Thermodynamics - definition
- B. Equivalence of heat and work as two forms of energy
  - 1. Work - definition
  - 2. Energy - definition
- C. Thermodynamics equilibrium
  - 1. Definition
  - 2. Thermodynamic state or processes

Reference 2, Chapter 21

Unit 2. Mechanical Equivalent of
- A. James Prescott Joule - short history
- B. Mechanical equivalent of heat - definition
- C. Joules constant - definition
  - 1. $J = 4.186$ joules/cal (metric units)
  - 2. $J = 778$ ft - 16/Btu (engineering units)

Unit 3. Law of Conservation of Energy
- A. Definition
- B. Mechanical energy input
- C. Heat energy input

Unit 4. First Law of Thermodynamics
- A. Internal energy function
- B. Definition - 1st law
- C. Mathematical statement - 1st law
- D. P-V diagram representing gas expanding at constant pressure

Unit 5. Adiabatic Processes
- A. Definition
- B. Adiabatic processes as applied to the first law
- C. Graphic illustration of an adiabatic process
- D. Throttling process

Unit 6. Isochoric Process
- A. Definition
- B. Isochoric process as applied to the first law
- C. Graphic illustration of an isochoric process

Unit 7. Isothermal Processes
- A. Definition
- B. Isothermal process as applied to the first law

STUDENT ACTIVITY

Laboratory Activity I:

Using a cardboard tube and lead shot, determine the amount of work done in joules, or the mechanical equivalent of heat when raising a known mass of lead shot the distance of the cardboard tube.

MODULE: THERMODYNAMICS - SECOND LAW

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Understand the second law of thermodynamics.

(2) Calculate efficiency and draw the P-V diagram of the following engines:
   - a) Carnot engine
   - b) Internal combustion engine
   - c) Steam engine
   - d) Refrigerator.

RATIONALE:

Heat engines generate energy in many different forms. The generation of energy in any form is of great importance to the solar student since solar energy is only one of the many forms of energy. The study of heat engines will broaden the horizon and possibly assist the solar student in future new designs of solar equipment.

REFERENCES:

(1) Tippens, Paul, Applied Physics, McGraw-Hill Co., N.Y., 1978.

(2) Harris/Hemmerling, Introductory Applied Physics, McGraw-Hill Co., N.Y., 1980.

(3) Dossat, Roy J., Principles of Refrigeration, John Wiley and Sons, N.Y., 1978.

UNIT TITLES:

(1) Second Law of Thermodynamics

(2) Heat Engines - Carnot Cycle

(3) Heat Engines - Internal Combustion Cycle

(4) Heat Engines - Steam Engines

(5) Refrigeration - COP

VOCABULARY:

Second Law of Thermodynamics
Carnot Cycle
Four-Stroke Engine
Compression Stroke
Exhaust Stroke
Reciprocating Steam Engines
Steam Turbine
COP
Heat Engine
Internal Combustion Cycle
Intake Stroke
Combustion/Power Stroke
Compression Ratio
Rankine Cycle
Refrigeration

Reference 1, Chapter 21

- Unit 1. Second Law of Thermodynamics
  - A. Second law - definition
  - B. Heat engine
    - 1. Definition
    - 2. Efficiency
- Unit 2. Heat Engines - Carnot Cycle
  - A. Sadi Carnot - short history
  - B. Carnot engine
    - 1. Definition
    - 2. P-V diagram of the ideal Carnot cycle
  - C. Efficiency of a Carnot engine
- Unit 3. Heat Engines - Internal Combustion Cycle
  - A. Internal combustion engine - four stroke engine (Otto cycle)
    - 1. Intake stroke
    - 2. Compression stroke
    - 3. Combustion/power stroke
    - 4. Exhaust stroke
  - B. Internal combustion cycle as indicated on a P-V diagram
  - C. Compression ratio - definition
  - D. Efficiency

Reference 2, Chapter 16

- Unit 4. Heat Engines - Steam Engines
  - A. Reciprocating steam engines
    - 1. Basic principles
    - 2. Rankine cycle - idealized steam cycle
    - 3. Rankine cycle as indicated by a P-V diagram
  - B. Steam turbine
    - 1. Basic principles
    - 2. Horsepower developed by a steam turbine
    - 3. Steam turbines as a source for electrical energy

Reference 3, Chapter 7

- Unit 5. Refrigeration - COP
  - A. Refrigeration - heat engine operated in reverse
  - B. Coefficient of performance - COP
    - 1. Definition
    - 2. Mathematical formula
  - C. Schematic diagram of refrigeration cycle

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Recognize the most commonly used solar system fluids and be familiar with their properties.

(2) Understand and calculate the design parameters for a water, phase change, or rock bed storage.

(3) Recognize the most commonly used refrigerants and be familiar with their properties.

(4) Be knowledgeable and familiar with the safety and economic considerations of refrigerants.

RATIONALE:

Heat transfer fluids are used in any active solar heating system. The thermodynamic properties of these fluids are extremely important in the design and sizing of a solar system and a storage system. Since air conditioning is becoming more important to the solar industry's future, a working knowledge and understanding of refrigerants can be of great value to the student.

REFERENCES:

(1) Howell/Bereny, Engineers Guide to Solar Energy, Solar Energy Information Service, California, 1979.

(2) Colorado State University, Solar Heating and Cooling of Residential Buildings, Sizing, Installation and Operation of Systems, U.S. Department of Commerce, 1980.

(3) Dossat, Roy J., Principles of Refrigeration, John Wiley and Sons, N.Y., 1978.

UNIT TITLES:

(1) Heat Transfer Fluids

(2) Thermal Storage Systems

(3) Refrigerants

(4) Safety

(5) Economic Considerations

VOCABULARY:

Ethylene Glycol

Phase Change Materials

Refrigerant

Propylene Glycol

Rock Bed Storage

Reference 1, Chapter 5

Unit 1. Heat Transfer Fluids
- A. Fluids commonly used in solar systems
  - 1. Water
  - 2. Ethylene glycol
  - 3. Propylene glycol
  - 4. 50/50 mixtures of water and glycol
  - 5. Oil
  - 6. Air

Reference 2, Module 8

- B. Basic properties of each fluid:
  - 1. Density
  - 2. Specific gravity
  - 3. Viscosity
  - 4. Boiling/freezing point
  - 5. Specific heat
- C. Examples of systems using each fluid

Unit 2. Thermal Storage Systems
- A. Water tanks and locations
  - 1. Heat storage capacity
  - 2. Recommended water volume /ft^2 for specific conditions
- B. Phase - change storage
  - 1. Definition - phase change material
  - 2. Types of phase change materials
  - 3. Properties of phase change materials
- C. Rock bed storage - air as a fluid
  - 1. Operating range
  - 2. Stratification
  - 3. Design parameters
  - 4. Pressure losses

Unit 3. Refrigerants

Reference 3, Chapter 16

- A. Refrigerant - definition
- B. Thermodynamic properties of specific refrigerants

Unit 4. Safety
- A. Toxicity of refrigerants
- B. Flammability and explosiveness of refrigerants
- C. American standard safety code for mechanical refrigeration

Unit 5. Economic Considerations
- A. Properties of refrigerants which effect capacity and efficiency
- B. Effects of moisture

ENERGY SCIENCE II

Semester Hours Credit: 4
Lecture: 3
Lab: 3

Project Director: Charles G. Orsak, Jr.

Prime Author: James T. Knowles

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INTRODUCTION:

Energy Science II is the second semester in the two semester sequence of Energy Science I-II. It is intended to give the student the necessary understanding of basic scientific principles necessary to understand the fundamentals of passive and active solar systems and other energy conservation considerations.

COURSE DESCRIPTION:

Topics covered are: elements of astronomy and geography necessary to understand the variations in solar insolation; the basics of atomic and nuclear physics necessary to understand the sun's processes; the nature of light, its propagation, and devices to collect this solar radiation; and fundamentals of electricity and magnetism and the relation of these principles to AC and DC circuits and devices.

COURSE PREREQUISITES:

Algebra (2 years High School or 1 year College level)
Energy Science I (May be waived with permission of the instructor)

COURSE OBJECTIVES:

Upon completion of this course the student should be able to:

(1) Apply the physical laws covered in the course to describe important features of a solar energy system.

(2) Exhibit a working knowledge of energy conservation principles.

(3) Appreciate the importance of obtaining an ability to explain phenomenon in addition to using them so that the knowledge is transferable to new technology.

COURSE DESIGN:

The course is designed so that material introduced early in the semester that might seem difficult will be covered again later in the semester in a different setting. This "spiral approach" allows for repeated reinforcement of certain difficult topics.

ENERGY SCIENCE II

COURSE CALENDAR:

WEEK NO. ASSIGNMENT	SUBJECT	LAB
1	Introduction & Review	Measure Skills
2	Celestial Mechanics & Geography	Solar Angle
3	Atomic & Nuclear Physics	Spectra
4	Periodic Motion	SHM, Wave Motion
5	Physical Optics	Interference, Diffraction
6	Geometrical Optics	Reflection, Mirrors
7	Geometrical Optics	Refraction, Lenses
8	Electrostatics	Electric Fields
9	DC Circuits	Ohm's Law
10	DC Circuits/ Magnetism	Magnetic Fields
11	Magnetism	Force on a conductor,DC motor, meters
12	Electromagnetism	Induced Effects
13	Elect/AC Circuits	Transformers/ Generators
14	AC Circuits	AC Resonance
15	AC Circuits	Photovoltaics
16	Control Theory	Control Devices

MODULE INDEX

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APPENDICES

A. Math Proficiency Test...............III-59

B. Graphing Techniques.................III-73

C. Laboratory: Measurement of
Solar Angle.............III-89

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Exhibit the necessary mathematical skills required to successfully complete the course.

(2) Demonstrate the measurement skills and data analysis techniques needed to perform typical laboratory experiments.

(3) Use important definitions from Energy Science I that will be used in Energy Science II.

RATIONALE:

Successful completion of Energy Science II requires certain mathematical and laboratory techniques. In addition to these skills the student needs a minimal working vocabulary from Energy Science I. It is normally assumed all of this information was obtained in ES I. Thus, the purpose of this unit is to review this information, identify those students who need additional help, and provide review materials for those students who require it.

REFERENCES:

(1) Harris, Experiments in Applied Physics, 3rd Ed., McGraw-Hill, 1980.

(2) Cioffari and Edmonds, Experiments in College Physics, 6th Ed., Heath, 1978.

(3) Dossat, Principles of Refrigeration, 2nd Ed., John Wiley & Sons, 1978.

UNIT TITLES:

(1) Algebra

(2) Graphing

(3) Measurement Instruments

(4) Energy Science I Terminology

VOCABULARY:

Algebra

Term

Coefficient

Inverse

Product

Quotient

Factor

Graphing

Axis

Abscissa

Ordinate

Coordinate

Linear

Exponential

Measurement

Micrometer

Calipers

Triple Beam Balance

Percent Error

Units

Energy Science I

Displacement

Velocity

Acceleration

Kinetic Energy

Potential Energy

Power

Pressure

Thermal Energy

Density

Newton's Laws of Motion

Appendix A - Math Proficiency Test	Unit 1. Algebra A. Give algebra proficiency test B. Direct students to appropriate supplementary material
Appendix B - Graphing Techniques Module	Unit 2. Graphing A. Discuss elements of making graphs B. Give homework assignment at end of graphing materials
	Unit 3. Measurement Instruments (LAB) A. Set up lab test to test students on use of: 1. Micrometer calipers 2. Vernier calipers 3. Triple beam balance 4. Steel rule
Reference 1, Exp. 1, p.1 Reference 2, Exp. 1, p.1	B. Require students to calculate area, volume, and density for standard shapes 1. Rectangular block 2. Right circular cylinder 3. Sphere
Reference 3, Chapter 1	Unit 4. Energy Science I - Terminology A. Review material in any standard physics text sufficient to cover vocabulary listed B. Dossat has a good review of these items in Chapters 1 & 2 - most physics texts cover these in more detail than a quick review would warrant C. The purpose of this section is a quick review of a large number of terms necessary to proceed successfully in Energy Science II

MODULE: CELESTIAL MECHANICS, GEOGRAPHY, AND SOLAR ENERGY

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the attraction between planetary bodies through the gravitational interaction and the central force required for circular motion, then use these forces to explain how planets move and in particular how the earth, moon, and sun move with respect to one another.

(2) Describe how solar radiation varies with the seasons according to location on the earth.

(3) Know the definitions of longitude and latitude on the earth, and solar altitude and azimuth.

(4) Define earth and solar time.

RATIONALE:

If a student is to understand the variation of seasonal solar insolation he/she must be able to visualize the earth's orbit about the sun and the inclination of the earth's axis to that orbit. Furthermore, he/she must be able to describe how these changes vary with location on the earth.

REFERENCES:

(1) Busche, Principles of Physics, 4th Ed., McGraw-Hill, 1982.

(2) Abell, Realm of Universe, 2nd Ed., Saunders, 1980.

(3) Berman, Exploring the Cosmos, Little, Brown & Co., 1973.

UNIT TITLES:

(1) Newton's Law of Gravitation

(2) Circular Motion

(3) Planetary Motion (Zodiac)

(4) Earth's Rotation on its Axis

(5) Geographical Terminology

(6) Earth and Solar Time

VOCABULARY:

- Newton's Law of Gravitation
- Inverse Square Law
- Central Force
- Celestial Plane
- Inclination
- Revolution
- Rotation
- Zodiac
- Horoscope
- Precession
- Solar Insolation
- Latitude
- Longitude
- Solar Altitude
- Solar Azimuth
- Earth Time
- Solar Time
- Equinox
- Solstice
- Sideral Day

MODULE: CELESTIAL MECHANICS, GEOGRAPHY, AND SOLAR ENERGY

Reference 1 - Chapter Reference 2, Chapter 1, pp. 7-8	Unit 1. Newton's Law of Gravitation
	A. Describe Newton's Law of Gravitation
	B. Define inverse square law and give other examples 1. Electrostatic force law (Coulomb's) 2. Force between magnetic poles
	C. Relations between the magnitudes of the basic forces of nature 1. Gravitational 2. Electromagnetic 3. Weak nuclear 4. Strong nuclear
	Unit 2. Circular Motion
	A. Centrifugal and central force
Reference 1, Chapter 6	B. Distinguish between a body in circular motion being pulled in and the common misconception of being "thrown out"
	Unit 3. Planetary Motion
Reference 2, pp. 27-30 Reference 2, pg. 29	A. Relate gravitation force as the central force causing planetary "circular" motion
	B. Briefly describe Kepler's Laws of Planetary Motion
Reference 3, pp. 23-24	C. Define the celestial sphere, plane, and equator
Reference 2, pp. 18-19	D. Relate briefly the zodiac and astrology to celestial position of sun in the skies
Reference 2, pp. 45-48	Unit 4. Earth's Rotation on Its Axis
	A. Describe the inclination of the earth's axis with respect to the revolutionary plane
	B. Describe the procession of this axis - relate to the motion of a top or gunscope
	C. Describe effects on solar insolation of the tilting of the earth's axis

Reference 2, pg. 51

Unit 5. Geographical Terminology
A. Define longitude and latitude
B. Define the Tropics of Cancer and Capricorn and relation to solar insolation
C. Define the equinox and solstices and relate to solar insolation
D. Define solar altitude and azimuth to location of sun in the sky
E. Lab - measurement of solar insolation vs. time of day and time of year

Appendix C - Lab on measurement of solar angle - NOTE: This lab begins this week and continues through the semester.

Reference 2, pp. 59-64

Unit 6. Earth and Solar Time
A. Define earth time
B. Define apparent and mean solar time
C. Define time standards

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the general features of the atomic model.

(2) Describe the general features of atomic bonds.

(3) Distinguish between conductors, insulators, and semiconductors.

(4) Describe the general features of the nucleus.

(5) Explain briefly fission and fusion.

(6) Describe the solar furnace.

RATIONALE:

As with all sections to this point, the purpose of this module is to introduce the student to the general features of the atom and the nucleus. It is not expected to cover this material in detail at this point. Certain features of these models will be discussed later in the course. At this point if a reasonable picture of the sun's processes are obtained it will suffice. Specifically, this material will be studied in more detail when photovoltaics is discussed.

REFERENCES:

(1) Jones, Chemistry, Man and Society, 2nd Ed., Saunders, 1976.

(2) Daniels, The Sun, Wiley, 1979.

(3) Romer, Energy An Introduction To Physics, Freeman, 1976.

(4) Busche, Principles of Physics, 4th Ed., McGraw-Hill, 1982.

(5) Abell, Realm of Universe, 2nd Ed., Saunders, 1980.

UNIT TITLES:

(1) Atomic Model

(2) Atomic Bonding

(3) Nuclear Model

(4) Nuclear Fusion and Fission

(5) Solar Processes

VOCABULARY:

Electron
Energy Levels
Proton
Charge
Neutron
Nucleus
Spectra
Periodic Table
Ionic Bonding
Solar Model

Metals
Conductors
Energy Bands
Semiconductors
Insulators
Fusion
Fission
Radioactivity
Nuclear Power

Reference 4 - Chapter 27
Reference 5, p. 78-82
Reference 3, Chapter 12

Unit 1. Atomic Model
- A. Describe the general features of the atomic model - electron, neutron, proton
- B. Describe the energy level concept - relate to atomic spectra
- C. Lab - do a demonstration lab to show the spectra of various elements and discuss the relationship to energy levels
- D. Lab - demonstration of charge to mass ratio experiment
- E. Lab - Millikan oil drop experiment - to measure quantization of charge
- F. Discuss periodic chart

Reference - Any Intro Chemistry Text
Reference 1, Chapter 9

Unit 2. Atomic Bonding
- A. Describe ionic bonding
- B. Describe covalent bonding
- C. Hydrogen bonding
- D. Metallic bonding
- E. Relate metallic bonding to the properties of metals
  - 1. Electrical conductivity
  - 2. Thermal conductivity
- F. Define conductor, semiconductor, and insulator - briefly discuss the characteristics of each

Reference 4, Chapter 28
Reference 3, Chapter 13

Unit 3. Nuclear Model
- A. Discuss the general model of the nucleus and the nuclear force
- B. Define isotope - relation to nuclear components (protons and neutrons)
- C. Define binding energy and relate to mass defect
- D. Describe nuclear decay and radioactivity

Reference 4, Chapter 28
Reference 3, Chapters 14, 15

Unit 4. Nuclear Fission and Fusion
- A. Discuss nuclear fission processes and products - relate the energy released
- B. Briefly discuss nuclear fission energy generation - pros and cons
  - 1. Availability of fuel
  - 2. Amount of energy/fuel used

        3. Costs
        4. Waste
    C. Discuss nuclear fusion process
    D. Discuss feasibilities of nuclear fusion energy methods near term - problems initial and control of process

Reference 2, Chapter 5

Unit 5. Solar Processes
    A. Discuss the formation of stars
    B. Describe solar fusion reactions
    C. Physical description of the sun
    D. Unexplained solar phenomena
        1. Solar prominences
        2. Solar shape
        3. Interior processes

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the characteristics of simple harmonic motion.

(2) Define the variables used to describe wave motion.

(3) List the types and characteristics of the waves in the electromagnetic spectrum.

RATIONALE:

This module introduces the student to the characteristics of periodic motion and wave motion. The module is preparatory for the study of light, its transmission, and its interaction with material objects.

REFERENCES:

(1) Cioffari and Edmonds, Experiments in College Physics, 6th ed., Heath, 1978.

(2) Bueche, Principles of Physics, 4th ed., McGraw-Hill, 1982.

(3) Cromer, Physics in Science and Industry, McGraw-Hill, 1980.

(4) Harris and Hemmerling, Introductory Applied Physics, 4th ed., McGraw Hill, 1980.

UNIT TITLES:

(1) Hooke's Law

(2) Simple Harmonic Motion

(3) Wave Motion

(4) Electromagnetic Spectrum

VOCABULARY:

- Amplitude
- Displacement
- Period
- Frequency
- Hooke's Law
- Elastic Potential Energy
- Simple Harmonic Motion
- Resonance
- Longitudinal Waves
- Transverse Waves
- Wavelength/Troughs/Crests
- Wave Velocity
- **Phase**
- Superposition
- Interference/Constructive-Destructive
- Standing Waves
- Nodes/Antinodes
- Electromagnetic Waves
- Radio Waves
- Infrared Waves
- Microwave
- Visible Light
- Ultraviolet
- X-rays
- Cosmic Rays

Reference 2, Chapter 13
Reference 1, Lab No. 12

Unit 1. Hooke's Law
- A. Description of law - linear relationship
- B. Lab - Proof of Hooke's Law

Reference 2, Chapter 13
Reference 4, Chapter 18

Unit 2. Simple Harmonic Motion
- A. Definition and requirements for simple harmonic motion
- B. Examples of simple harmonic motion
  1. Mass on a spring
  2. Simple pendulum
  3. Torsional pendulum
- C. Lab - measurement of period and frequency of objects in simple harmonic motion
  1. Mass on a spring
  2. Simple pendulum

Reference 2, Chapter 14
Reference 3, Chapter 11

Unit 3. Wave Motion
- A. Define the variables used to describe waves
  1. Wavelength (crests and troughs)
  2. Wave velocity
  3. Period
  4. Frequency
- B. Discuss the use of the equation $V=f\lambda$
- C. Discuss the principle of superposition
- D. DEMO: Demonstrate velocity of waves in different media, inversion of reflected pulses
- E. Define principle of superposition
- F. Define resonance and give examples
  1. Child in swing
  2. Musical instruments
  3. Standing waves on a string
- G. Define phase relation between interfering waves

Unit 4. Electromagnetic Spectrum
- A. Discuss relation between all electromagnetic waves
- B. Emphasize nature of electromagnetic wave - not mechanical in nature
- C. List types of electromagnets

MODULE: LIGHT - PHYSICAL OPTICS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Name and explain the classic experiments that prove the wave nature of light.

(2) Describe interference devices used for measuring wavelength, small distances, and resolution.

RATIONALE:

The material discussed in this module covers the wave nature of light including interference, diffraction, resolution, and the devices used to observe and apply these effects. This material will be of particular use to students who seek employment in a research-related occupation.

REFERENCES:

(1) Bueche, *Principles of Physics*, 4th Ed., McGraw-Hill, 1982.

(2) Cromer, *Physics in Science and Industry*, McGraw-Hill, 1980.

(3) Harris and Hemmerling, *Introductory Applied Physics*, 4th Ed., McGraw Hill, 1980.

(4) Filmstrip: *Interference: Principle of Superposition*.

UNIT TITLES:

(1) Interference and Diffraction

(2) Interference Patterns

(3) Interference Devices

(4) Resolution

VOCABULARY:

Diffraction
Coherent/Incoherent
Constructive Interference
Destructive Interference
Phase
Slit
Monochromatic
Interferometer
Grating
Optical Path Length
Thin Films
Newton's Rings
Order
Collimator
Spectrometer
Spectra
Spectra Lines
Resolution

Reference 1, Chapter 25
Reference 2, Chapter 13
Reference 3, Chapter 23

Unit 1. Interference and Diffraction
- A. Define diffraction - give examples to show relationship between size of wave and obstacle
- B. Review principle of superposition (see Module IV, Unit III C)
- C. Define constructive/destructive interference - relate to phase and difference of path length from single source

Filmstrip: Interference Principle of Superposition

- D. DEMO: dual trace scope - input two identical sources and vary phase to set up interference patterns
  - 1. Set up beat pattern to show interference between close but not identical sources
  - 2. Use identical tuning forks at various changing locations to cause constructive and destructive interference

Use Cornell Interference and Diffraction Slit Film Demonstration - mfd. by National Press, Palo Alto, California (available from Cenco or Sargent Welch)

- E. Describe Young's double slit experiment
- F. DEMO: show Young's double slit and grating demo

Unit 2. Interference Patterns
- A. Discuss maxima and minima
- B. Describe order of maxima and minima
- C. Introduce equation to calculate location of maxima and minima
- D. Describe factors that influence the separation of the ordered fringes

Unit 3. Interference Devices
- A. Michelson interferometer
  - 1. Describe operation and theory
  - 2. Discuss application to measuring small thicknesses
- B. Thin films
  - 1. Define equivalent optical path length

   2. Describe and explain phase change of a wave undergoing reflection from a more dense medium
   3. Discuss optical applications of thin films
      a. Coatings on lens
      b. Measurement of small thicknesses

C. Diffraction grating
   1. Describe operation
   2. Applications - grating spectrometer
      a. Reflection and transmission
      b. Describe spectra - relate to energy levels discussed in Module III

Unit 4. Resolution

A. Describe effects on diffraction of the relation between wavelength of incoming wave and size of obstacle

B. Relate above to limits of visible detail - limit of light microscope magnification

C. Shadowing effects caused by diffraction

MODULE: LIGHT - GEOMETRICAL OPTICS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the reflection and refraction of light geometrically and mathematically.

(2) Locate the nature, location, and size of images formed by reflective and refractive devices.

(3) Apply these principles to describe the optical properties of common optical devices, especially as relates to the collection of solar energy.

RATIONALE:

Since solar energy is concerned with collecting radiant energy this module will play an important part in understanding the operations of many devices with which the solar student will be working.

REFERENCES:

(1) Bueche, *Principles of Physics*, 4th Ed., McGraw-Hill, 1982.

(2) Cromer, *Physics in Science and Industry*, McGraw-Hill, 1980.

(3) Harris and Hemmerling, *Introductory Applied Physics*, 4th Ed., McGraw Hill, 1980.

(4) Cioffari and Edmonds, *Experiments in College Physics*, 6th Ed., Heath, 1978.

UNIT TITLES:

(1) Physical Characteristics of Light

(2) Reflection of Light

(3) Refraction of Light

(4) Image Location With Mirrors/Reflective Devices

(5) Image Location With Lens/Refractive Devices

VOCABULARY:

Angstrom
Microns
Crests, Troughs
Reflection
Refractive Index
Nanometer
Wavefront
Ray
Law of Reflection
Reflection Coefficient Transmission

Refraction
Total Internal Reflection
Image
Object Distance
Focal Length
Radius of Curvature
Convex Mirror
Converging/Diverging
Magnification
Thin Lens Formula
Convex Lens
Chromatic Aberration
Simple Magnifier
Fresnel Lens

Snell's Law
Object
Vertex
Image Distance
Principal Axis
Plane Mirror
Concave Mirror
Mirror Equation
Ray Diagrams
Concave Lens
Spherical Aberration
Diopters
Focussing Collector
Beam

Reference 3

Unit 1. Physical Characteristics of Light

- A. Range of wavelengths for visible light
    - 1. Define units commonly used to measure light
    - 2. Give range of visible IR, UV
    - 3. Relate visible spectrum colors to wavelength
- B. Speed of light
    - 1. Describe types of experiments used to measure speed of light
    - 2. State speed of light
    - 3. Review use of $V=f\lambda$ for light and relate frequency and wavelength for visible light
- C. Refractive index
    - 1. Define index of refraction n with respect to speed of light in various media
    - 2. Give sample values of n
- D. Definitions
    - 1. Wavefronts
    - 2. Rays
    - 3. Beams
    - 4. Phase
    - 5. Plane wave
    - 6. Crests
    - 7. Troughs

Reference 4, pg. 265,
Experiment 38,
Black Board,
Optics Kit from Pasco
Scientific, 1933 Republic
Avenue, San Leandro, Ca.,
94577, (415) 351-1501

Unit 2. Reflection of Light

- A. Description of the reflection of a wave
- B. Discuss the law of reflection
- C. Describe making of ray diagrams and ray tracing

LAB: Proof of law of reflection from flat and curved surfaces

- D. Define specular and diffuse reflection
- E. Discuss effects on solar collectors of reflection; define reflection coefficient/transmission coefficient

Unit 3. Refraction of light

- A. Describe the refraction of light as it passes from one medium to another
- B. Derive Snell's Law and give examples

Reference 4, pg. 265, Experiment 38

LAB: Proof of Snell's Law

- C. Define absolute and relative indices of refraction
- D. Discuss conditions for total internal reflection and give examples of applications (e.g. light pipes, prisms)

Unit 4. Image Location With Mirrors/ Reflection Devices

- A. Use ray diagram to trace location of image formed by a plane mirror
- B. Define object distance, image distance, virtual image, real image
- C. Use ray diagram to trace location of image formed by concave mirror
- D. Define principal axis, vertex, and magnification
- E. Develop mirror equation and calculate location of image for objects located at various object distances - confirm with ray diagrams
- F. Repeat C,D,E for convex mirrors
- G. Describe cylindrical mirrors
- H. Describe devices that use mirrors
  - 1. Concentrating reflective collectors
  - 2. Power towers
  - 3. Other light gathering application
    - a. Telescopes
    - b. Solar coolers
- I. Describe effects of spherical aberration and correction with parabolic surfaces

LAB: (1) Measurement of focal length of spherical mirrors, (2) Measurement of focusing collectors heating power

Unit 5. Image Location With Lenses/Refractive Devices

- A. Define converging and diverging lenses - give examples of characteristics that determine nature for various lenses
- B. Use ray diagrams to trace locations of images of objects located in front of converging lenses
- C. Develop lens equation and calculate location of images for objects located at various object distances; confirm with ray diagrams
- D. Repeat B and C for diverging lenses
- E. Describe cylindrical lenses
- F. Describe uses of refractive devices
  - 1. Concentrating refractive collectors
  - 2. Fresnel lenses
  - 3. Microscopes
  - 4. Magnifiers
  - 5. Telescopes
- G. Discuss effects of chromatic aberration on refractive devices and possible solutions

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe and calculate the electrical force on charged particles.

(2) Describe and calculate the electrical field around specific arrangements of charged particles.

(3) Describe and calculate the electric potential around specific arrangements of charged particles.

RATIONALE:

The purpose of this module is to introduce the student to the general characteristics of the electrostatic force. This will serve as a basis for understanding electrical circuits and DC devices in the next two modules.

REFERENCES:

(1) Bueche, Principles of Physics, 4th Ed., McGraw-Hill, 1982.

(2) Cromer, Physics in Science and Industry, McGraw-Hill, 1980.

(3) Harris and Hemmerling, Introductory Applied Physics, 4th Ed., McGraw Hill, 1980.

(4) Bell, Fundamentals of Electric Circuits, Reston, 1978.

(5) Sargent-Welch Scientific Co. - Institutions on use of Electric field mapping set. Catalog No. 1960.

UNIT TITLES:

(1) Description of The Atom: Review

(2) Charging Methods

(3) Coulomb's Law

(4) The Electric Field

(5) Electric Potential (Potential Difference)

VOCABULARY:

Atom
Electron
Neutron
Proton

Coulomb's Law
Coulomb
Field
Lines of Force

Insulator
Conductor
Valence
Electroscope
Induction
Conduction
Ground
Battery

Test Charge
Electric Potential (difference)
Volt
Capacitor
Condenser
Equipotential
Electric Potential Energy
EMF

Reference 1

Unit 1. Description of the Atom: Review
- A. Discuss the general feature of the nucleus
    - 1. Nucleus
        - a. Proton - size, charge
        - b. Neutron - size, charge
    - 2. Electrons - size, charge
- B. Describe the electrostatic force that holds the atom together - relate to planetary model
- C. Describe features of the atom that make elements, insulators, or conductors

Unit 2. Charging Methods
- A. Describe the electroscope - indicator of presence of charge
- B. Describe how to charge by conduction
- C. Describe how to charge by induction
- D. Discuss Faraday's "Ice Pail" experiment - emphasize location of excess charge on a conductor

Reference 9

Unit 3. Coulomb's Law
- A. Discuss the dependence of the electrostatic force on charged particles vs. distance - inverse square law
- B. State Coulomb's Law, relate to Newton's Law of Gravitation, and work examples
- C. Distinguish between excess charge on an object and amount of positive and negative charge on that object
- D. Emphasize vector nature of the force and the principle of supposition

Reference 4

Unit 4. The Electric Field
- A. Describe the gravitational field of the earth to introduce the concept of a field

B. Relate this gravitational field to the electric field about a point charge - introduce concept of test charge to indicate presence of the field.

Reference 5, Electric Field

STUDENT ACTIVITY

Laboratory:

Draw the electric field about two oppositely charged points, charged plates, and observe effects of conductors and insulators in an electric field.

C. Describe and calculate the electric field about a point charge and between charged plates
D. Indicate vector nature of field and relate to principle of superposition

Unit 5. Electrostatic Potential
A. Describe a capacitor
B. Define potential in terms of work required to move the charge between two points - define the volt
C. Define equipotential lines and planes - relate to lab experiment of electric field description
D. Define electric potential energy function
E. Describe batteries as a source of EMF's

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Discuss the characteristics of the basic elements of DC circuits.

(2) Use Ohm's Law.

(3) Describe a capacitor and calculate the charge stored in a capacitor.

(4) Use Kirchoff's Rules to determine the voltage across and current through resistors in series and/or parallel.

(5) Calculate the charge on and voltage across capacitors in series and/or parallel.

RATIONALE:

This material is basic to understanding circuits that students will be working with in the control and use of active solar energy systems.

REFERENCES:

(1) Bueche, Principles of Physics, 4th Ed., McGraw-Hill, 1982.

(2) Cromer, Physics in Science and Industry, McGraw-Hill, 1980.

(3) Harris and Hemmerling, Introductory Applied Physics, 4th Ed., McGraw Hill, 1980.

(4) Diefenderfer, Principles of Electronic Instrumentation, Saunders, 1972.

(5) Bell, Fundamentals of Electric Circuits, Reston, 1978.

(6) Slemon and Traughen, Electric Machines, Addison Wesley, 1980.

(7) Ciofarri and Edmonds, Experiments in College Physics, 6th Ed., Heath, 1978.

MODULE: DC CIRCUITS AND DEVICES

UNIT TITLES:

(1) Current

(2) Electrical Circuits

(3) Ohm's Law

(4) Kirchoff's Law - Series/Parallel Circuits

(5) Capacitors

(6) Capacitors in Series and Parallel

VOCABULARY:

Current
Resistance
Voltmeter
Series
Dielectric
Capacitor
Voltage Drop
Watts

Ampere
Ohm
Ammeter
Parallel
Circuit
Farad
Power

Reference 5

Unit 1. Current
- A. Describe the motion of charges in electric fields - relate motion of charges from regions of high potential to low potential
- B. Define current/amperes

Unit 2. Electrical Circuits
- A. Describe elements necessary to make simple electrical circuits/give examples
- B. Define resistance
- C. Relate flow of current through resistors to flow of water through pipes

Unit 3. Ohm's Law
- A. Describe Ohm's Law (I x V)
- B. Define unit of resistance - Ohm
- C. Emphasize empirical nature of Ohm's Law and indicate examples where Ohm's Law is not valid
- D. Describe ammeter/voltmeter - construction and function
- E. Discuss placement of these meters in circuits

Unit 4. Kirchoff's Law - Series Parallel Circuits
- A. Discuss Kirchoff's point rule for currents
- B. Discuss Kirchoff's loop rule for voltages
- C. Calculate the net resistors
- D. Calculate the voltage across and current through resistors in series or parallel

Reference 7, Experiment 24

- E. Laboratory: Ohm's Law series/parallel circuits
- F. Calculate the power "consumed" in resistors

Unit 5. Capacitors
- A. Describe charging of a capacitor by a DC source
- B. Define the unit of capacitance: farad
- C. Calculate the capacitance of a flat plate capacitor with and without a dielectric

D. Indicate typical values of capacitance

E. Describe and calculate storage of energy in a capacitor - indicate use in AC circuits for later reference

Unit 6. Capacitors in Series/Parallel

A. Calculate the equivalent capacitance of capacitors in series or parallel

B. Calculate the voltage across and charge on capacitors in series or parallel

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe magnetic fields around various magnetic shapes and current configurations.

(2) Describe the right hand rules for:
   a) Magnetic field configurations,
   b) Forces on moving charger in magnetic fields, and
   c) Forces on currents in magnetic fields.

(3) Describe the construction of various electromechanical devices:
   a) Meters
   b) Motors.

RATIONALE:

The solar student will be working with many types of meters and motors, and this unit serves as an introduction to those devices. Additionally, the material in this unit is preparatory to the study of AC circuits and electromagnetic interactions.

REFERENCES:

(1) Bueche, Principles of Refrigeration, 4th Ed., McGraw-Hill, 1982.

(2) Cromer, Physics in Science and Industry, McGraw-Hill, 1980.

(3) Harris and Hemmerling, Introductory Applied Physics, 4th Ed., McGraw-Hill, 1980.

(4) Miller, Physics Fun and Demonstration, Cenco Press, 1969.

(5) Bell, Fundamentals of Electric Circuits, Reston, 1978.

(6) Sargent-Welch Scientific Co. - Instructions for use of magnetic field balance. Catalog No. 2339.

(7) Cioffari and Edmonds, Experiments in College Physics, 6th Ed., Heath, 1978.

UNIT TITLES:

(1) Plotting Magnetic Fields

(2) Magnetic Fields of Current Configurations

(3) Force on a Current in a Magnetic Field

(4) Electromechanical Devices

VOCABULARY:

North/South Pole
Compass
Field Lines
Magnetic Field Strength
Flux Density
Magnetic Induction
Tesla
Weber
Gauss
Toroid
Electromagnet
Galvanometer
Ammeters
Voltmeters
Motor
Flux
Solenoid

Reference 7, Lab 22

Unit 1. Plotting Magnetic Fields
- A. Lab Plotting magnetic fields
- B. Describe use of a compass as a device to measure presence, direction, and relative magnitude of a magnetic field

Unit 2. Magnetic Fields of Current Configurations
- A. Describe the magnetic field around current configurations
  - 1. Straight Line
  - 2. Solenoid
  - 3. Toroid
- B. Describe use of right hand rule for determining field direction
- C. Calculate the magnitude of the B field for the straight line current, solenoid and toroid

Reference 6
Laboratory: Measurement of force on a current
Demo. Reference 4

Unit 3. Force on a Current in a Magnetic Field
- A. Calculate the magnitude of the force on a current in a B field
- B. Use the right hand rule to determine direction of force on the B field
- C. Demonstrate force on a moving charge in an evacuated tube - have a magnet bend the beam - discuss RH Rule
- D. Calculate torque on a current loop

Unit 4. Electromechanical Devices
- A. Relate all meters to galvanometers and discuss construction of galvanometer
- B. Discuss electrical modifications to adjust range of DC ammeters

C. Discuss electrical modifications to convert galvanometer to voltmeter and adjust ranges of DC voltmeter

D. Discuss basic operation of a DC motor -
   1. Compare and contrast with the galvanometer
   2. Describe the slip ring - current reversing device

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Apply Faraday's Law to calculate the magnitudes of induced EMF's in a variety of situations used to change the flux.

(2) Apply Terry's Law (in conjunction with the appropriate right hand rules) to determine the direction of the induced EMF's and currents.

(3) Define inductance and describe the relation between induced EMF's and changing current.

(4) Describe the effects of induced emf's in generators, motors, and transformers.

RATIONALE:

This material introduces the interactive effects between varying electric and magnetic fields. This material is necessary for an understanding of AC circuits and components.

REFERENCES:

(1) Cioffari and Edmonds, Experiments in College Physics, 6th Ed., Heath, 1978.

(2) Bueche, Principles of Physics, 4th Ed., McGraw-Hill, 1982.

(3) Cromer, Physics in Science and Industry, McGraw-Hill, 1980.

(4) Romer, Introductory Applied Physics, Freeman, 1976.

(5) Bell, Fundamentals of Electric Circuits, Reston, 1978.

UNIT TITLES:

(1) Flux

(2) Induced EMF's - Faraday's Law

(3) Lenz' Law

(4) Inductance

(5) Electromagnetic Devices

VOCABULARY:

Flux
Flux Density
Weber
Primary
Secondary
Turns
Induced EMF
Frequency
Mutual Induction
Self Induction
Henry
Motional EMF
AC Generator
Back EMF
Counter EMF
Angular Frequency

Reference 4

Unit 1. Flux
- A. Define flux and webers
- B. Calculate flux for a variety of examples involving a fixed or variable field, loop area, loop orientation

Reference 1, Lab 33

Unit 2. Induced EMF's - Faraday's Law
- A. Laboratory - Observation of induced EMF's in a variety of situations
- B. Discuss experiment performed to relate magnitude of EMF induced to
  - 1. Size of B field change
  - 2. Number of coils in secondary loop
  - 3. Rapidity of change
  - 4. Area of loop
- C. Introduce Faraday's Law and make quantitative calculations on the value of the induced EMF as a function of the parameters discussed above

Reference 4

Unit 3. Lenz' Law
- A. State Lenz' Law
- B. Discuss examples related to experiment performed in Unit 2 to explain direction of induced current
- C. Relate Lenz' Law to conservation of energy

Reference 2

Unit 4. Inductance
- A. Rewrite Faraday's Law in terms of $\Delta i/\Delta t$ instead of $\Delta\phi/\Delta t$
- B. Define mutual inductance - emphasize it depends on the physical construction (size, number of turns) of the coils, but in general only the result is of interest
- C. Define self inductance - same emphasis
- D. Calculate induced EMF's for several situations involving variable currents

Reference 1, Lab 33

Unit 5. Electromagnetic Devices

A. Lab - generator, transformer

B. AC generator: describe the construction and operation of an AC generator

C. Discuss nature of induced EMF from an AC generator - sinusoidal

D. DC motors - discuss back or counter EMF in DC motors - describe protective effect and calculate difference in current in rotating and non-rotating cases

E. Describe how a motor "burns out"

F. Transformers - introduce transformers - use example of ignition coil for pulsing DC

MODULE: AC CIRCUITS/DEVICES

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the effect of resistors, inductors, and capacitors in AC circuits singularly and in combination.

(2) Distinguish between maximum and RMS or effective voltage and current.

(3) Discuss resonance condition and calculate resonant frequency.

(4) *Briefly* describe generation and reception of radio waves.

(5) Describe operation of transformer and its application to AC power distribution.

(6) Discuss the diode, semiconductor devices, and applications of electronic devices (meters, motors).

(7) Discuss integrated circuits - construction and function.

(8) Discuss solar/electrical conversion - photovoltaics.

RATIONALE:

The material in this module covers a broad range of topics that can not possibly be covered in depth in this short time period. It is intended as an introduction to the material, with the idea that other courses will extend the student's knowledge in these areas.

REFERENCES:

(1) Bueche, *Principles of Physics*, 4th Ed., McGraw-Hill, 1982.

(2) Cromer, *Physics in Science and* , McGraw-Hill, 1980.

(3) Harris and Hemmerling, *Introductory Applied Physics*, 4th Ed., McGraw-Hill, 1980.

(4) Bell, *Fundamentals of Electric Circuits*, Reston, 1978.

(5) Slemon and Straughen, *Electric Machines*, Addison Wesley, 1980.

(6) Winsco Product Instruction - ES1 - Wabash Instrument Corporation, P.O. Box 707, Wabash, Indiana.

MODULE: AC CIRCUITS/DEVICES

UNIT TITLES:

(1) Resistance in an AC Circuit

(2) Capacitance in an AC Circuit

(3) Inductance in an AC circuit

(4) R-L-C Circuits - Resonance

(5) Generation and Reception of Radio Waves

(6) The Transformer - Power Distribution

(7) Electronic Devices

(8) Photovoltaics

VOCABULARY:

Resistance
RMS (or effective) Current
RMS (or effective) Voltage
Capacitive Reactance
Inductive Reactance
Impedance
Resonant Frequency
Radio Waves
Transformer
Step Up
Step Down
Diode
Triode
Grid
Plate
Cathode
Photovoltaics
Anode
Sinusoidal
Rectify
Semiconductor
IC
Chip
Thermionic
Filament
Hole
N-Type
P-Type
Filter

Reference 1
Reference 4

Unit 1. Resistance in an AC Circuit
- A. Calculate the effect of a resistor in an AC circuit
- B. Define RMS values of current and voltage
- C. Calculate power in pure resistive AC circuit

Unit 2. Capacitance in an AC Circuit
- A. Discuss phase relationship between the current and charge or voltage on a capacitor in a capacitive AC circuit
- B. Calculate X_c, the capacitive reactance
- C. Discuss dependence of X_c on f and C
- D. Calculate the power in pure capacitive circuits

Reference 4

Unit 3. Inductance in AC Circuits
- A. Discuss phase relationships between the current and voltage in inductive AC circuits
- B. Introduce "ELI the ICE" man as a monic device to remember phase relationships
- C. Calculate X_L - the inductive reactance
- D. Discuss dependence of X_L on f and L
- E. Calculate the power in a pure inductive AC circuit

Unit 4. RLC Circuits - Resonance
- A. Discuss phasor diagrams to show phase relationship between current I and voltage E across resistors, inductors, and capacitors in RLC circuits
- B. Define and calculate impendence Z, discuss dependence of Z upon frequency
- C. Describe counter effects of X_L and X_C on phase angle between E and I
- D. Define resonant frequency and calculate f_o for several examples

Reference 6

E. Laboratory - AC circuits - lab to observe effects of R, L, and C in DC and AC circuits and to calculate and observe resonant frequency in an AC circuit
F. Calculate the power, and power factor, and phase angle for an RLC circuit

Reference 2

Unit 5. Generation ad Reception of Radio Waves
A. Briefly discuss the tank circuit and relate to pendulum for energy considerations
B. Discuss simple radio transmitter and how the RF wave is generated
C. Describe simple radio receiver and how the RF is received

Unit 6. The Transformer - Power Distribution
A. Discuss use of transformer to step up or step down AC voltages
B. Describe the effect on power losses in AC power transmission due to high values of current
C. Describe application of transformer to minimize power losses

Reference 5

Unit 7. Electronic Devices
A. Describe the thermionic emission process and the simple design of vacuum tube diode/rectification
B. Define semiconductors and describe how these devices can be used to be a diode and cause rectification
C. Introduce integrated circuits - their construction and applications

Reference 5

Unit 8. Photovoltaics

A. Lab - Demonstration of photovoltaic devices

B. Describe the process of conversion of solar energy to electrical energy

C. Give update on current status of production - watervats and cast, availability, and applications

D. Future prospects of widespread use

MODULE: CONTROL THEORY/CONTROLS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Have a limited working knowledge of information theory.

(2) Have a working knowledge of control theory and devices used in implementing this theory.

(3) Describe various transducers' construction and application.

RATIONALE:

This section is intended as a review and "Tie Together" module. All of the material in this module has been described in part in previous modules. The purpose of discussing the material is to tie loose ends together and review practical applications.

REFERENCES:

(1) Cromer, *Physics in Science and Industry*, McGraw-Hill, 1980.

UNIT TITLES:

(1) Information Theory

(2) Control Theory

(3) Transducers

VOCABULARY:

Transducer
Channel Capacity
Feedback (Positive and Negative)
Output
Thermal Transducer
Mechanical
Bit
Control
Input
Phototransducer
Acoustic Transducer
Video

Reference 1

Unit 1. Information Theory
- A. Define bit
- B. Define and calculate information content
- C. Define capacity of a channel

Unit 2. Control Theory
- A. Define control
- B. Define feedback
- C. Give examples of positive and negative feedback and how this feedback is used to control a system

Unit 3. Transducers
- A. Define Transducers
- B. Describe various transducers, construction and operation
  1. Photo transducer
  2. Thermal transducer
  3. Acoustic transducer
  4. Mechanical transducer
  5. Video transducer

APPENDICES

A. Math Proficiency Test..III-59

B. Graphing Techniques..III-73

C. Laboratory - Measurement of Solar Angle..........................III-89

APPENDIX A

N.B.: It is intended that this serve as a guide to making a relevant test for your particular class. This is a copy of a placement test used by a Math department.

NOTE: THE RESULTS OF THIS TEST WILL BE USED FOR ADVISEMENT ONLY. YOU WILL BE ADVISED AS TO WHICH COURSE IS SUGGESTED TO BEST MEET YOUR PARTICULAR PROGRAM. DO NOT FEEL THREATENED BY THE TEST; WE ARE USING IT TO HELP YOU AND NOT TO COERCE YOU INTO ANY COURSE.

DIRECTIONS: This test consists of four sections.

(a)	Less than 1 year of high school algebra,	need take only Section I;
(b)	1 year or more of high school algebra but less than 2 years,	need take only Section I & II;
(c)	2 years of high school algebra and are majoring in anything except math or science,	need take only Sections I, II, & III;
(d)	2 years of high school algebra and trigonometry and are majoring in math or science,	need to take all four Sections.

You will not be penalized in any way for taking more of the test than you need, so if you are in doubt as to whether an additional section applies to you, go ahead and take it.

Do not write on the test copy. Consider each problem carefully, find the correct answer among the five choices following, and shade the appropriate space on the answer sheet. If a problem seems too difficult, make a careful guess and continue to the next problem. Your score is the number of correct answers marked; there is no penalty for guessing.

Use a number 2 pencil in marking your answers and do all your work on scratch paper. You have a maximum time of 60 minutes to complete the sections of the test which apply to you.

Write your full name and your student number in the space provided on your answer sheet.

Section I

1. Which of the following is equal to 23.015 + .25 + 175?

   (a) 198.04

   (b) 198.40

   (c) 23.440

   (d) 198.265

   (e) 23.430

2. Place $\frac{3}{20}$, $\frac{4}{10}$, and $\frac{1}{4}$ in order with the smallest number first, then the next smallest, and finally the largest.

   (a) $\frac{1}{4}$, $\frac{3}{20}$, $\frac{4}{10}$

   (b) $\frac{3}{20}$, $\frac{1}{4}$, $\frac{4}{10}$

   (c) $\frac{4}{10}$, $\frac{3}{20}$, $\frac{1}{4}$

   (d) $\frac{3}{20}$, $\frac{4}{10}$, $\frac{1}{4}$

   (e) none of these

3. Which of the following is equal to $5\frac{1}{4} \div \frac{7}{3}$?

   (a) $\frac{9}{4}$

   (b) $\frac{4}{9}$

   (c) $\frac{3}{4}$

   (d) $\frac{9}{7}$

   (e) none of these

4. Which of the following is equal to $\frac{8}{7} - \frac{4}{6}$?

   (a) 4

   (b) $\frac{10}{42}$

   (c) $\frac{4}{13}$

   (d) $\frac{10}{21}$

   (e) $\frac{34}{21}$

5. Which of the following is equal to -7(12-9)-3?

   (a) 63

   (b) 18

   (c) 24

   (d) -96

   (e) none of these

6. Which of the following is equal to 81.472 ÷ 1.52?

   (a) .536

   (b) 601.7

   (c) 5.36

   (d) 60.17

   (e) 53.6

7. What number is 70 percent of 65?

   (a) 46

   (b) approximately 93

   (c) 45.5

   (d) approximately .01

   (e) none of these

8. Which of the following is equal to $2^3 \cdot 3^2 \cdot 5$?

   (a) 360

   (b) 180

   (c) 3125

   (d) 15625

   (e) none of these

Section II

9. The value of x which satisfies the equation $6x - 55 = 3x$ is :

(a) 5

(b) 7

(c) 15

(d) -7

(e) none of these

10. Simplify $2x + 3y - [(5y - 4x^2) - 8y]$

(a) $12\,x^3y^3$

(b) $6x^3 + 6y^2$

(c) $4x^2 + 2 + 3y$

(d) $2x - 4x^2$

(e) none of these

11. Simplify $(2ab^3)\,(3a^3b)$

(a) $6\,a^4b^4$

(b) $6\,a^3b^3$

(c) $(6\,ab)^3$

(d) $5\,a^4b^4$

(e) $5\,a^3b^3$

12. Simplify $\frac{4a-2b}{2a+4b}$

(a) 0

(b) $\frac{a-b}{a+b}$

(c) $\frac{2}{3}$

(d) $\frac{2a-b}{a+2b}$

(e) -1

13. The value of x which satisfies the equation $\frac{x}{2} + 3 = \frac{2x}{3}$ is:

(a) $\frac{1}{2}$

(b) 2

(c) 18

(d) 9

(e) 3

14. Which one of the following is a factor of $x^2 - 5x - 6$?

(a) $x - 3$

(b) $x + 3$

(c) $x - 6$

(d) $x - 1$

(e) none of these

15. Simplify $\frac{-6a^3b}{15ab^4}$

(a) $\frac{-2a^2}{5b^3}$

(b) $\frac{-2a^4}{5b^5}$

(c) $\frac{-2a^3b^4}{3}$

(d) $-\frac{2}{5}\ a^{-2}b^{-3}$

(e) none of these

16. Simplify $\sqrt{8}\ -2\sqrt{50}$

(a) $-2\sqrt{42}$

(b) $-8\sqrt{2}$

(c) $-46\sqrt{2}$

(d) -8

(e) none of these

17. Which of the following is equal to $\frac{4}{x-2} + \frac{3}{2x+3}$

(a) $\frac{7}{3x+1}$

(b) $\frac{11x+6}{(x-2)\ (2x+3)}$

(c) $\frac{7}{(x-2)\ (2x+3)}$

(d) $\frac{5}{2x}$

(e) none of these

18. Which of the following will be true for any integer x?

(a) (c), (d), and (e)

(b) (c) and (d) only

(c) $3 + (x+5) = (3+x) + 5$

(d) $3 (x5) = (3x) \cdot 5$

(e) $3 \cdot 5(x+5) = (3 \cdot x) + (3 \cdot 5)$

19. The product of (x+4) and (x-3) is:

(a) $x^2 - 12$

(b) $x^2 + 12$

(c) $x^2 - x + 12$

(d) $x^2 + x + 12$

(e) $x^2 + x - 12$

20. If x represents my age now, which phrase represents a number that is 7 less than my age 2 years from now?

(a) $2x - 7$

(b) $7 - 2x$

(c) $7 - (x+2)$

(d) $(x-2) - 7$

(e) $x - 5$

Section III

21. The value(s) of x which satisfy $5 - 4x \geq 7$ is (are):

(a) $x > -\frac{1}{2}$

(b) $x \leq -3$

(c) $x = -\frac{1}{2}$

(d) $x \geq -3$

(e) $x \leq -\frac{1}{2}$

22. Simplify $(2x^3 - 3x^2 + x - 1) \div (x+1)$

(a) $2x^2 - 5x + 6$

(b) $2x^2 + 5x + 4 + \frac{5}{x+1}$

(c) $2x^2 - 5x + 6 + \frac{7}{x+1}$

(d) $2x^2 - 5x + 6 - \frac{7}{x+1}$

(e) $2x^2 - x + \frac{-1}{x-1}$

23. If $f(x) = 2x^3 - x^2 + 1$, then $f(2)$ is which of the following?

(a) 2

(b) 0

(c) 13

(d) 61

(e) none of these

24. Which of the following is the sum of the values of x and y which satisfy the equations $2x - 4y = -6$, $3x + y = 5$ (HINT: solve for x and y and then add these values)?

(a) 1

(b) -3

(c) -2

(d) 2

(e) 3

25. The value(s) of x which satisfy the equation $\frac{2}{x} + \frac{2}{x-3} = 1$ is (are):

(a) -3, 2

(b) 6, 1

(c) 6, -1

(d) 1

(e) 3, 2

26. Simplify $\frac{a^2 + 6a + 9}{a^2 + 3a + 2} \cdot \frac{3a + 3}{a^2 - 9}$

(a) $\frac{3(a+3)}{(a+2)\ (a-3)}$

(b) $\frac{6}{a-3}$

(c) $-\frac{3}{a+2}$

(d) $\frac{a^3 + 18a^2 + 27}{a^4 + 3a^3 - 18}$

(e) $\frac{3}{a+2}$

27. If $R = \frac{v^2}{2c} + h$, then c is which of the following?

(a) $\frac{2(R-h)}{v^2}$

(b) $\frac{v^2}{2(R-h)}$

(c) $\frac{v^2 + h}{2R}$

(d) $\frac{v^2(R-h)}{2}$

(e) none of these

28. If $|a| = a$ when $a \geq 0$ and $|a| = -a$ when $a < 0$, then for what values of x is it true that $|x-5| = x-5$?

(a) $x \leq 0$

(b) $x > 0$

(c) $x \geq 5$

(d) $x < 5$

(e) $x \leq 5$

29. Simplify $(16\,a^4x^{16})^{\frac{1}{2}}$

(a) $4\,a^2x^4$

(b) $4\,a^2x^8$

(c) $8\,a^2x^8$

(d) $256\,a^8x^{32}$

(e) $16\,a^4x^4$

30. If $\log 2^8 = x$, then x is:

(a) 3

(b) 2

(c) 10

(d) 8

(e) 4

31. Using the formula $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$, which of the following value(s) of x satisfy the equation $-2x^2 - 3x + 3 = 0$

(a) $\frac{-3\pm\sqrt{33}}{-4}$

(b) $\frac{3\pm\sqrt{-33}}{-4}$

(c) $\frac{3\pm\sqrt{33}}{-4}$

(d) $\frac{3\pm\sqrt{-15}}{-4}$

(e) none of these

32. Simplify $\frac{\sqrt{5}}{\sqrt{5} - \sqrt{10}}$

(a) $-1 + \sqrt{2}$

(b) $5\sqrt{2-1}$

(c) -1

(d) $1 + 5\sqrt{2}$

(e) none of these

33. Which of the following is an accurate description of the equation $x(x-5)=0$?

(a) a linear equation with root 5

(b) a linear equation with root -5

(c) a quadratic equation with roots $\pm\sqrt{5}$

(d) a quadratic equation with roots 0 and -5

(e) a quadratic equation with roots 0 and 5

34. The equation of line M is:

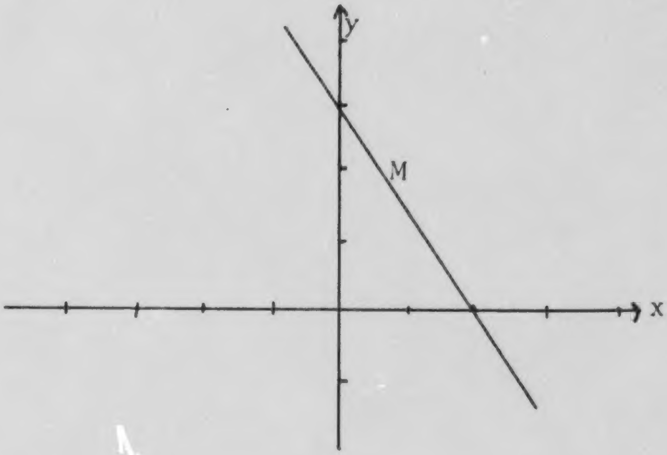
(a) $3x + 2y = 6$

(b) $3x - 26 = 6$

(c) $3x^2 + 2y = 12$

(d) $2x + 3y = 9$

(e) $2x - 3y = -9$



Section IV

35. Factor $1 - x$ as the difference of two squares.

    (a) $(1 + \sqrt{x})\ (1 - \sqrt{x})$

    (b) $(1 - x^2)\ (1 + x^2)$

    (c) $(\sqrt{x} - 1)\ (\sqrt{x} + 1)$

    (d) $(1 - \sqrt{x})^2$

    (e) none of these

36. The product of $(5 - 2i)$ and $(4 + 3i)$ is:

    (a) 33

    (b) $26 - 7i$

    (c) 19

    (d) $14 - 7i$

    (e) none of these

37. The value of θ which satisfies the equation $3 \text{Sin}\,\theta = 1 + 2 \text{Sin}\,\theta$ where $0 \leq \theta < 2\pi$ is:

    (a) $\frac{\pi}{3}$

    (b) $-\frac{3\pi}{2}$

    (c) π

    (d) 0

    (e) $\frac{\pi}{2}$

APPENDIX B

In technical fields, graphing is often used as a method of expressing experimental data relating two or more physical quantities. Graphing provides a method for concise presentation that otherwise might take several pages to present in words. Thus, the technical student must be able to construct and interpret graphs.

Upon completion of this exercise you should be able to:

(1) Plot graphs representing the relationship between two quantities; and

(2) Interpret data given in graphical form.

To accomplish the two objectives expressed above, you must:

(1) Define the terms abscissa, ordinate, and independent and dependent variables; and

(2) Define the slope of a straight line.

GRAPHING

The first step in the preparation of a graph is to construct a set of axes on a sheet of graph paper. The axes consist of a pair of perpendicular lines - one horizontal and the other vertical. The axes should be constructed well inside the margins of the graph paper to leave room for labeling, tilting, and appropriate comments. See Figure 1.

FIGURE 1

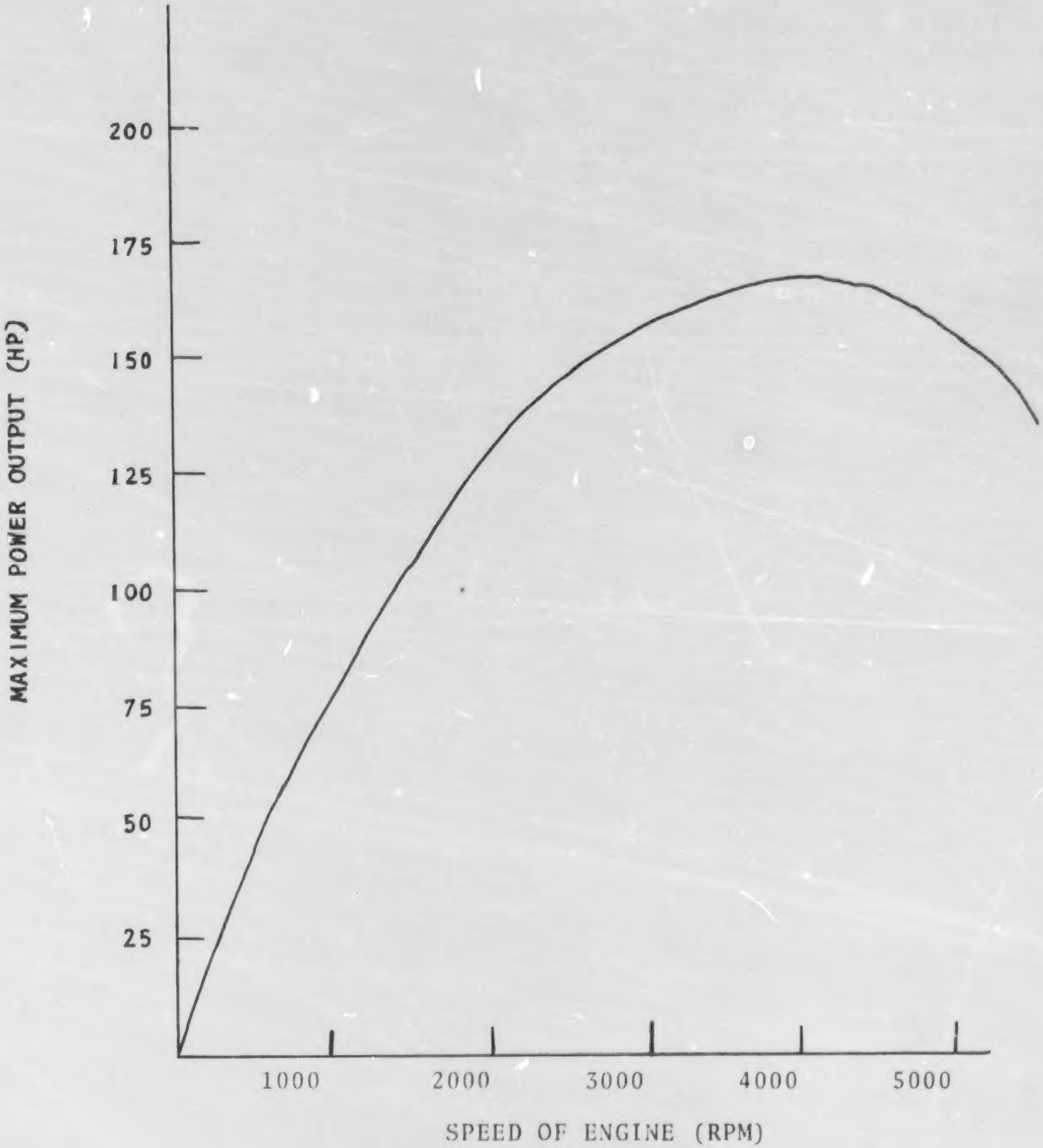

MAXIMUM POWER OUTPUT (HP)
200
175
150
125
100
75
50
25
1000
2000
3000
4000
5000
SPEED OF ENGINE (RPM)

FIGURE 2

The second step is to establish a scale along each of the axes. The scale will be determined, of course, by the values of the quantities being plotted. There are several factors to consider in choosing the scales. Consider Figure 2 illustrating the graph of the power output versus the speed of an engine.

(a) The scale for the independent variable (the quantity that the investigator controls) is placed along the horizontal axis. The axis is then labeled with the quantity being scaled and the units in which that quantity is being measured. In Figure 2, the horizontal axis is labeled "SPEED OF ENGINE (RPM)." The speed of the engine is the quantity; it is measured in rpm's or revolutions per minute.

(b) The scale for the dependent variable (the quantity that changes as the independent variable is varied is placed along the vertical axis. In Figure 2, the vertical axis is labeled "MAXIMUM POWER OUTPUT (HP)." The quantity being scaled is the maximum power output; it is measured in hp, or horsepower.

(c) The magnitude of the scale is chosen so that the graph will essentially fill the graph paper. The same scale need not be used for both axes, and indeed it cannot in most cases.

Now, to check your understanding of the graphing concepts just presented, answer the following questions.

(1) In Figure 2, why is the engine speed scaled on the horizontal axis?

(2) In Figure 2, why is the maximum power output scaled on the vertical axis?

(3) In Figure 2, why is the horizontal axis scaled such that one major division equals 1,000 rpm?

(4) In Figure 2, why is the vertical axis scaled such that one major division equals 25 hp?

The answer to question one should reflect the concept that the engine speed was controlled by a test engineer and was therefore the independent variable. Thus, it was plotted on the horizontal axis. The answer to question two should reflect the concept that the power output varied as a result of the change in engine speed. Power output, therefore, was the dependent variable and was plotted on the vertical axis.

Answers to questions three and four should reveal the magnitudes of the scales are chosen so that the graph will fill allotted space. In the Figure 2 example, data indicated that the maximum value of engine speed was 5000 rpm and the maximum power output approached 175 hp. Thus, the scales were chosen to spread the data over the entire sheet of graph paper.

Consider the following description of a study of driving distances.

> The distance a car travels is being determined at certain intervals of time. The experimenter is driving along a straight road which has distance markers every 10 ft. He checks to see how far he has gone every 10 seconds. The experiment is concluded at the end of 100 seconds at which time he has traveled 2200 ft.

(5) On the sheet of graph paper labeled Figure 3, draw, label, and scale a set of axes so that the data of the experiment described above could be graphed. Remember to follow the guidelines concerning independent and dependent variables and magnitude of the scales.

A correct set of axes is shown in Figure 4. Since readings of distance are taken every ten seconds, time is the variable under the control of the investigator. Thus, time is the independent variable and is plotted along the vertical axis.

Once the design of the graph is completed, the actual plotting of points occurs. A point on the graph represents the data the experimenter obtains. Consider the power output/engine speed graph of Figure 2. How did the test engineer know to draw the graph shown? A test on the engine was performed and the set of measurements presented in Table 1 was obtained.

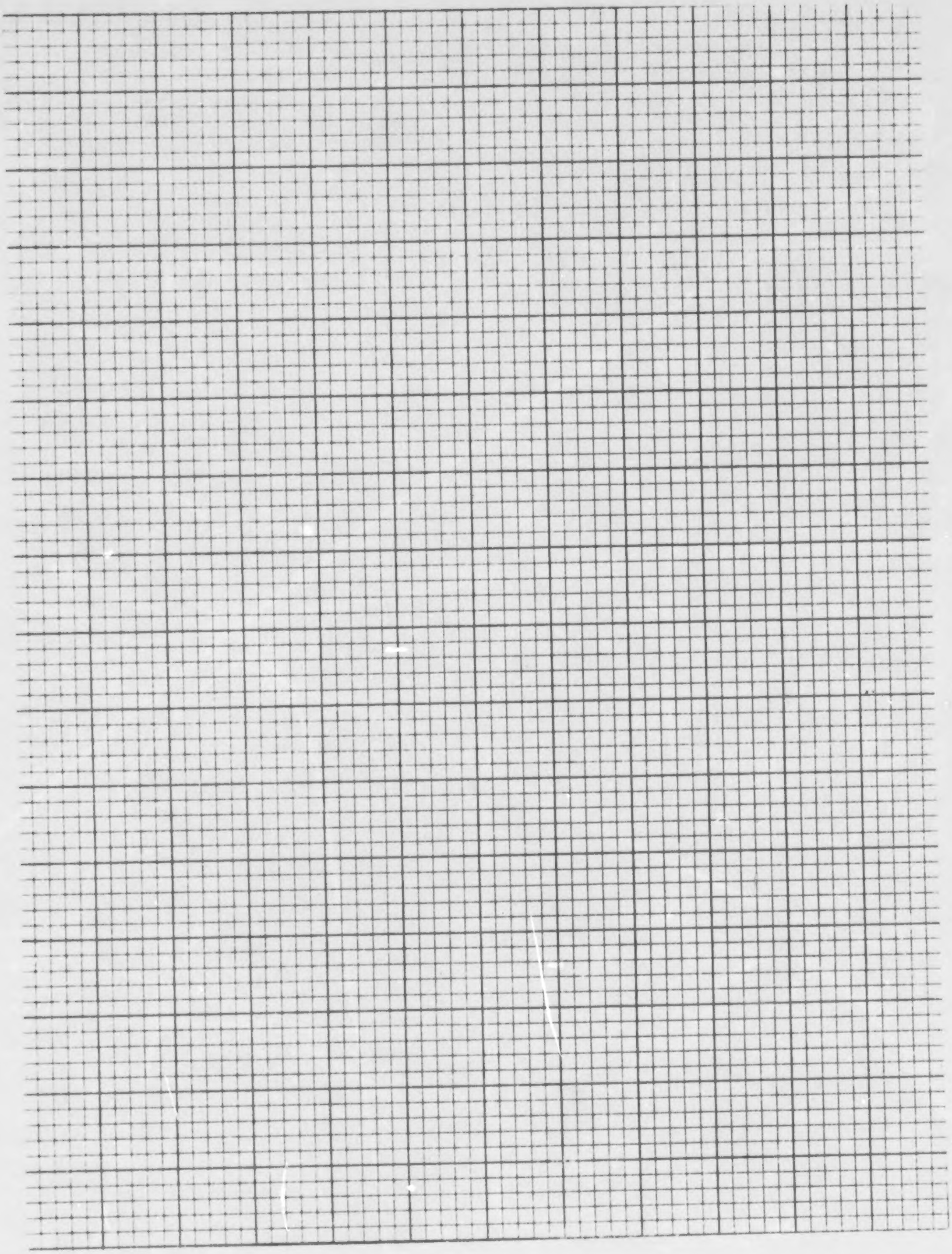


FIGURE 3

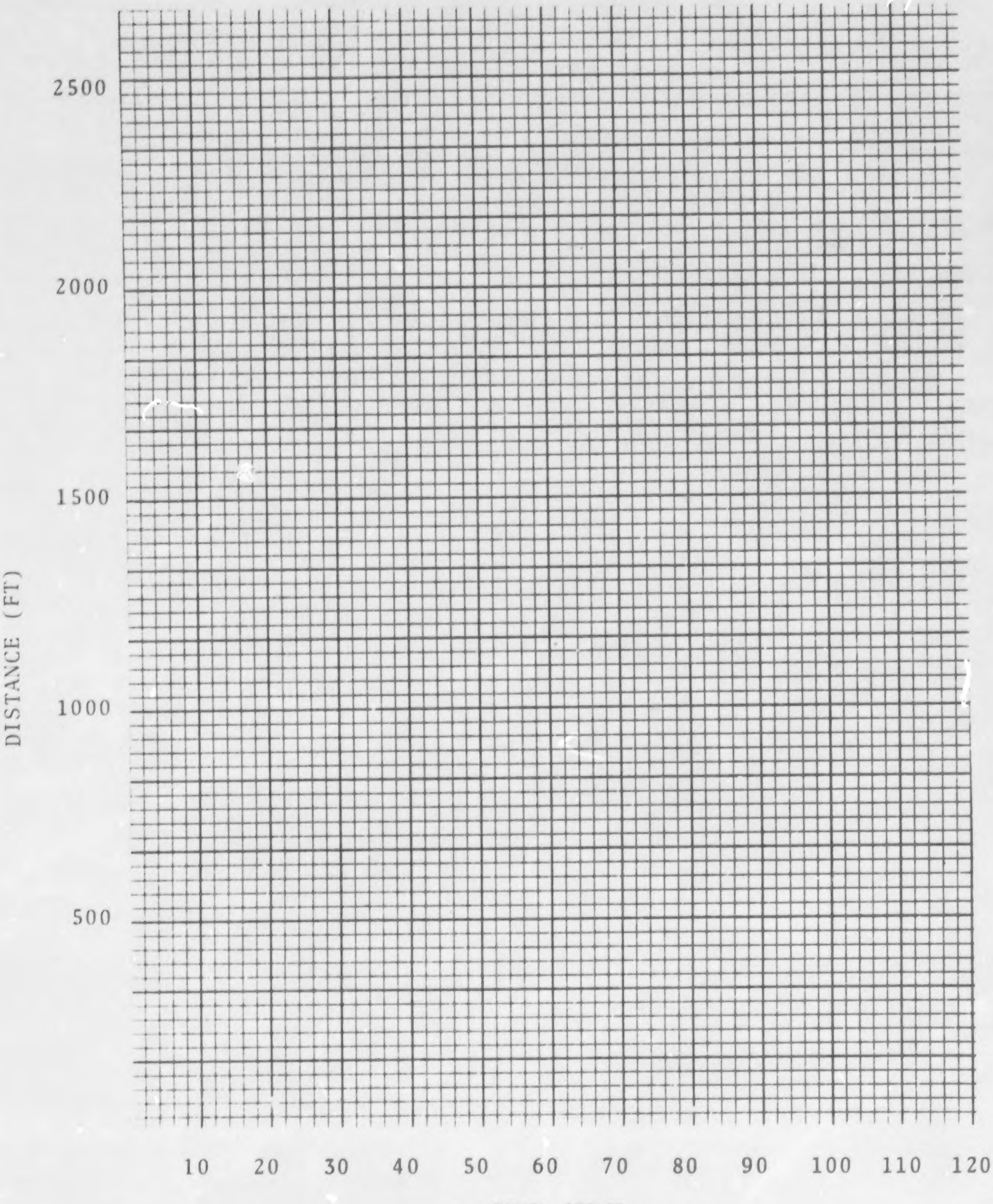

2500
2000
1500
1000
500
DISTANCE (FT)
10
20
30
40
50
60
70
80
90
100
110
120
TIME (SEC)

FIGURE 4

TABLE 1

Power Output vs. Engine Speed for Test Engine

ENGINE SPEED (RPM)	POWER OUTPUT (HP)
500	44
1000	75
1500	106
2000	125
2500	138
3000	151
3500	165
4000	172
4500	168
5000	125

The points on the graph in Figure 5 were plotted from the data in Table 1 in the following manner. Consider the first pair of values at 500 rpm, the maximum power output is 44 hp. To locate the point on the graph representing these values, first draw a vertical line through the point on the horizontal scale representing 500 rpm. Then draw a horizontal line through the point on the vertical scale representing 44 hp. The place where these two lines intersect is the point on the graph representing the experimental point. This set of construction lines is shown in Figure 5. The other points in Figure 5 were similarly plotted, but the construction lines are not shown. When using graph paper, with existing lines, drawing construction lines becomes necessary.

If all the points in Figure 5 are connected by a smooth, straight line the curve shown in Figure 2 results. (Note: The smooth curve does not pass through all data points. It is assumed that each point contains experimental error and thus may not fall exactly on the curve.)

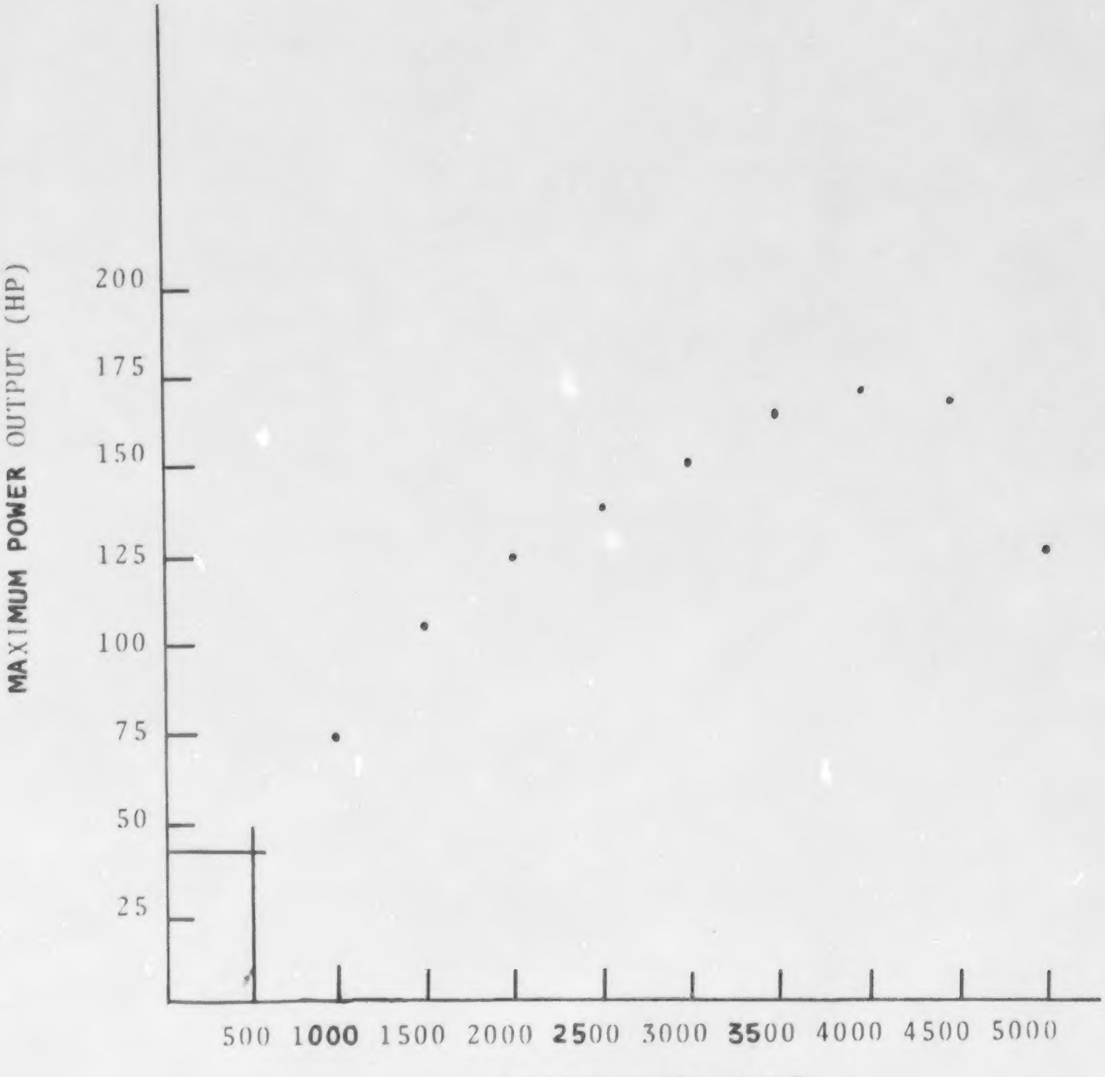

MAXIMUM POWER OUTPUT (HP)
200
175
150
125
100
75
50
25
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
ENGINE SPEED (RPM)

FIGURE 5

(6) Plot the data in Table 2 on the set of axes constructed in Figure 6. Then draw a smooth curve through the points.

TABLE 2

Velocity of Object in Free Fall vs. Time of Fall

TIME (sec)	VELOCITY (ft/sec)
0	0
1	32
2	63
3	92
4	120
5	145
6	167
7	186
8	198
9	208
10	215
11	221
12	225
13	227

The correct plot is shown in Figure 7. Check to see that your graph is the same by placing it on top of Figure 7 and holding them up to the light. The two graphs should be nearly superimposed. (Note: Graphs cannot be connected by smooth curves if the data points are not related to one another in a predictable manner.)

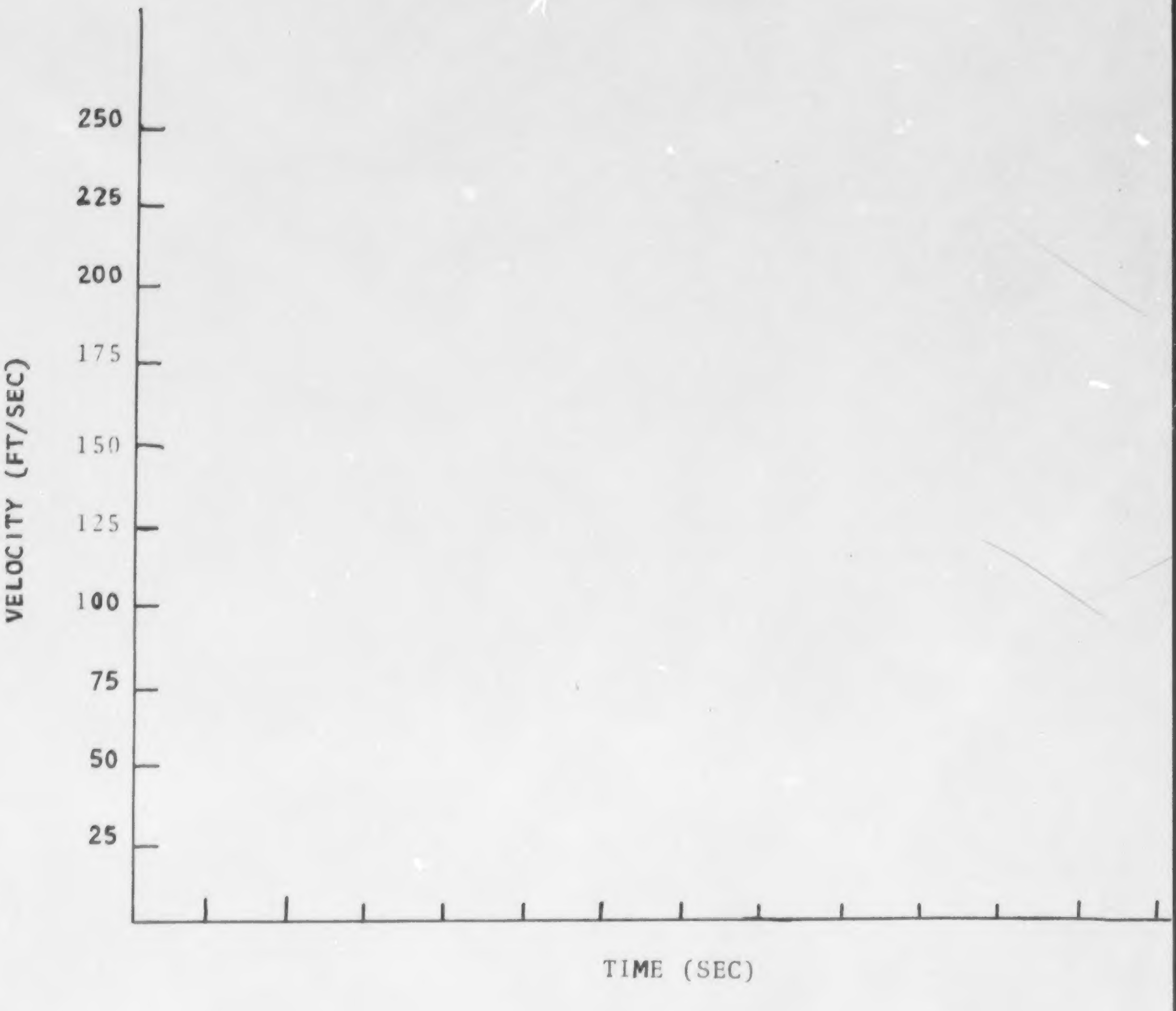


FIGURE 6

The last step in constructing the graph comes in giving it a title. The title should describe the information contained in the graph. Included should be a brief interpretation of the data.

(7) Suggest titles for the graphs in Figures 2 and 6.

Fig. 2: ____

Fig. 6: ____

Typical titles might be:

Fig. 2: Power output vs. Engine speed.

Peak power output at 4100 rpm.

Fig. 6: Velocity of Object in Free Fall
vs.
Time of Fall

Terminal velocity approximately 30 ft./sec.

Implied in composing the title is the ability to interpret the data shown in the graph. In Figure 2, the graph reaches a maximum height at 170 hp and 4100 rpm and then begins to drop off. Thus, the graph indicates that the power output of the engine increases as the engine speed increases up to 4100 rpm. But, further increases in engine speed beyond 4100 rpm decrease the maximum power output. The graph reveals how power output varies with engine speed. The "physics" of the situation will be used to explain why it happens.

In Figure 6, the velocity of a freely falling object is plotted versus time of fall. A terminal or final velocity is reached after about 14 to 15 seconds; that is, after 14 to 15 seconds the velocity stops increasing and remains constant. A typical example of behavior of this type is obtained with a parachute. The chutist reaches a terminal velocity (hopefully much less than 230 ft./sec. if his chute opens.)

Take the post-test that follows. It is to be turned in as a homework lesson.

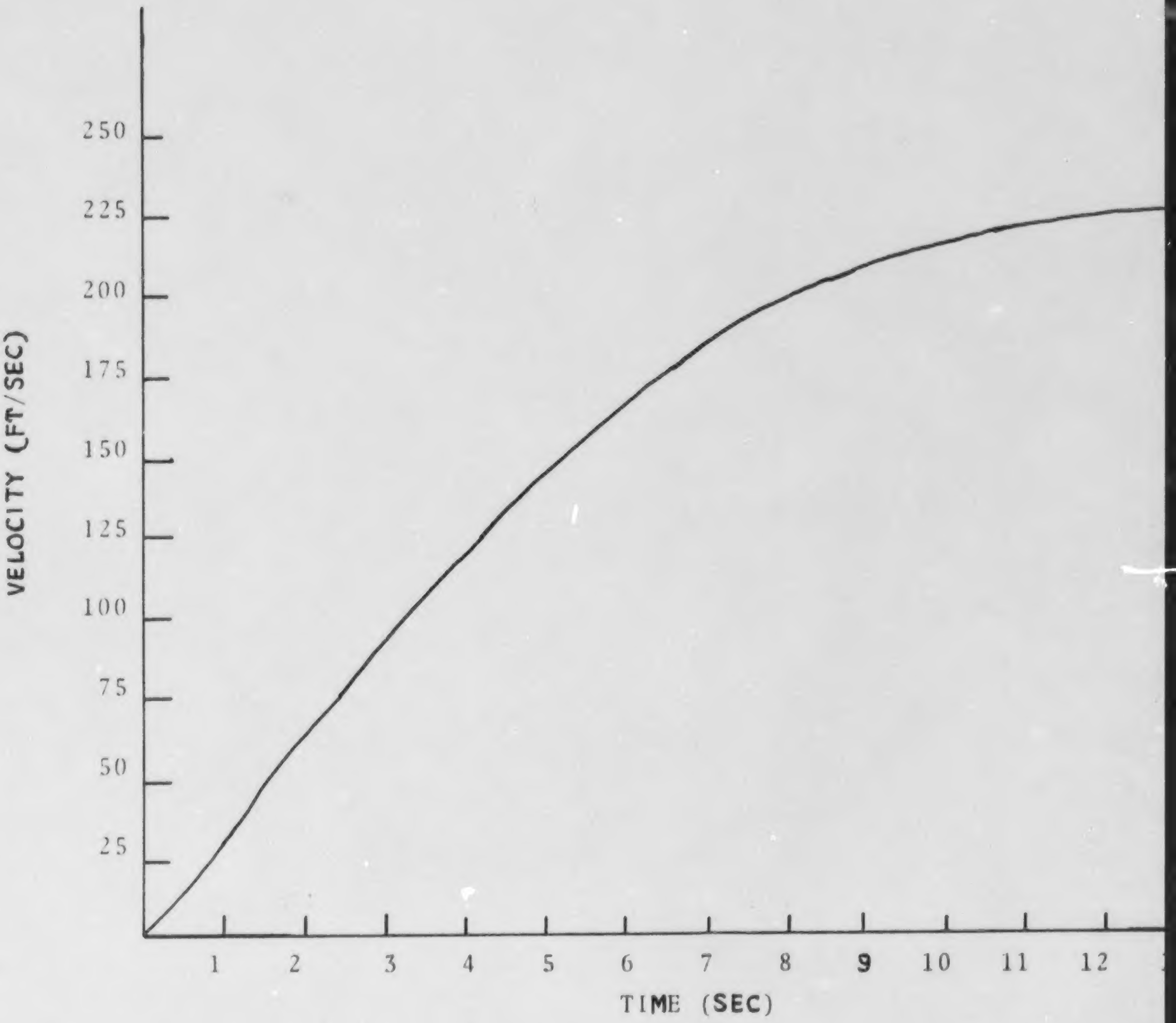

VELOCITY (FT/SEC)
250
225
200
175
150
125
100
75
50
25
1
2
3
4
5
6
7
8
9
10
11
12
TIME (SEC)

FIGURE 7

POST-TEST

For each of the experimental situations described below:

(a) **Draw, label,** and scale a set of axes.

(b) **Plot** the data.

(c) **Title** the graph.

(d) Give a brief interpretation of the data.

The **work** is to be done on graph paper. (Supplied by the student)

1. A car is traveling at an almost constant velocity of 50 ft./sec. A table of values of the distance the car has traveled at one second intervals is given below.

TIME (sec)	DISTANCE (ft)
0	0
1	50
2	99
3	149
4	197
5	252
6	299
7	347
8	400
9	450
10	499

2. An airplane is gaining altitude as it takes off. Following, is a table constructed from checking the plane's altimeter.

TIME (sec)	ALTITUDE (feet)
0	0
2	0
4	50
6	120
8	220
10	340
14	580
18	720

22	960
26	1000
30	1340
35	1640
40	1940
45	2200
50	2380
55	2470
60	2500
65	2500
70	2500

3. A man is rowing down a river. He has all of the intricate scientific equipment necessary to measure his velocity. He makes the measurements every hour for one complete day. The values he obtains are given below.

TIME	VELOCITY (MPH)	TIME	VELOCITY (MPH)
8am	7	8pm	5
9am	6	9pm	3
10am	5	10pm	3
11am	5	11pm	3
12noon	4	12midnight	3
1pm	3	1am	3
2pm	3	2am	3
3pm	3	3am	3
4pm	3	4am	3
5pm	7	5am	6
6pm	7	6am	5
7pm	6	7am	7

APPENDIX C

Determining the Altitude and Azimuth of the Sun

EXPERIMENT 1

OBJECTIVES:

Upon completion of this experiment, the student should be able to:

(1) To measure the altitude of the sun.

(2) To measure the azimuth of the sun.

INTRODUCTION:

This is perhaps the most fundamental of all solar energy experiments since it defines the behavior of the sun from which we expect to obtain energy. The determination of the sun's position in the sky at a given location on the earth's surface is important to our understanding of the varying amounts of solar energy we receive, as well as to our most efficient use of that energy.

You have observed the sun low in the eastern sky in the morning, highest in the sky at noon, and low in the western sky in the evening. This apparent motion of the sun is due to the axis rotation of the earth. Perhaps you have also observed how high the sun is at noon in early summer, while at noon in early winter it is much lower in the sky. This apparent change in the north-south position is due to the tilt of the earth's axis and the earth's revolution around the sun once each year. Figure 1-1 shows the position of the sun and its path across the sky for various times of the year. The shadows cast by a vertical post are also shown for corresponding sun positions. You can see that only twice a year does the sun rise due east of an observer and set due west. This occurs on the vernal equinox (March 21st) and on the autumnal equinox (September 21st). You can see from figure 1-2 that when the sun is highest in the sky on any day, the shadow cast at that time is shortest and the shadow line is aligned due north. You can check this by comparing the alignment with the North Star (Polaris) in an evening observation.

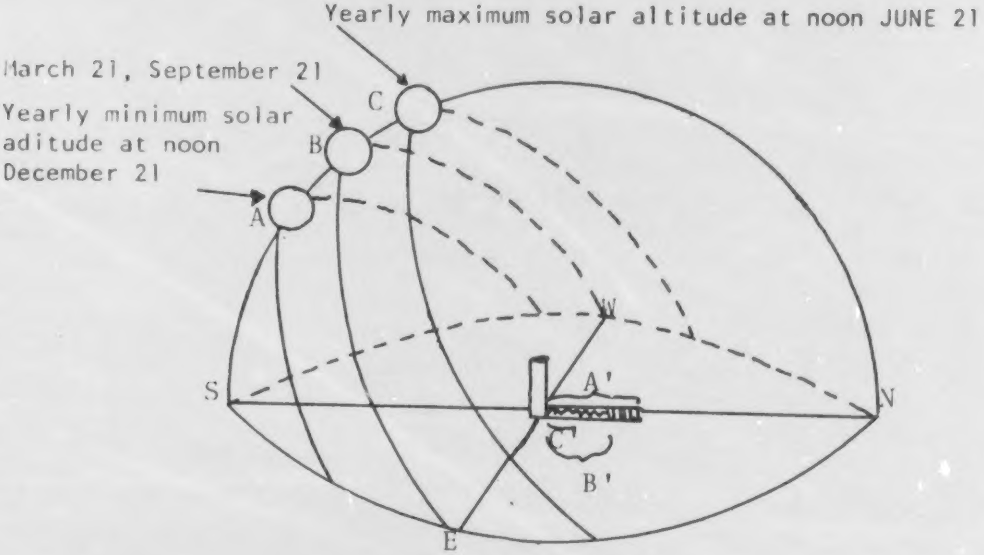

Yearly maximum solar altitude at noon JUNE 21
March 21, September 21
Yearly minimum solar aditude at noon December 21
C
B
A
W
A'
S
N
C'
B'
E

Figure 1-1

Various paths of the sun across the sky, and the corresponding shadow lengths at noon on the equinoxes and summer and winter solstices.

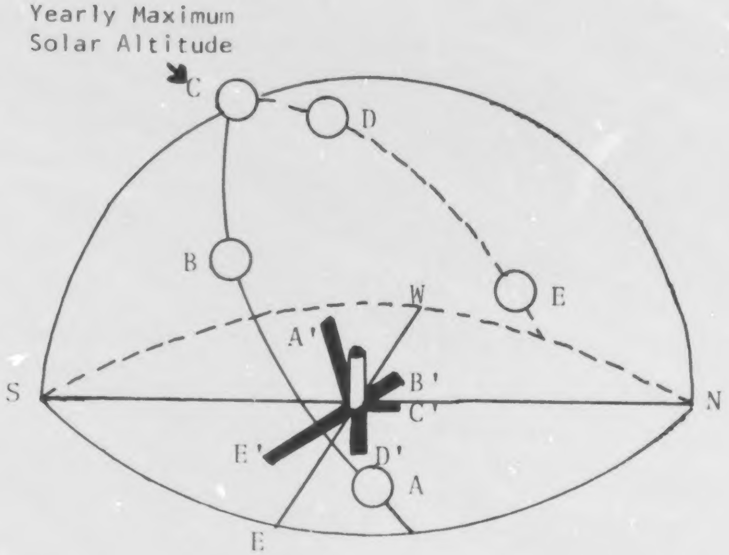

Yearly Maximum Solar Altitude
C
D
B
E
W
A'
B'
S
N
C'
E'
D'
A
E

Figure 1-2

Various shadow positions and lengths during the summer solstice.

You have also observed that temperatures are lower when the sun is low in the sky and are higher when the sun is high in the sky. This is because the heating effect of the sun's rays are the greatest when the sun's rays are direct - that is, they are striking a surface at an angle of 90^o. When the rays strike a surface at small angles, the same rays cover a much larger area, so that each unit area of surface receives less energy.

When the rays are striking the surface at 90^o, the angle of incidence is said to be zero, since, by convention, incident angles are measured with respect to a normal (perpendicular) to the surface at the point of incidence. When the angle of incidence is zero, the heating effect of the insolation (incoming solar radiation) is at a maximum, and when the angle of incidence increases to 90^o, the absorbed insolation decreases to zero. Thus, the intensity of solar radiation on a surface varies with the cosine of the incident angle of the sun's rays. For this reason, the effectiveness of any solar energy device will depend on its alignment with the sun. (See the GEOMETRIC ANALYSIS section showing these relationships.) In general, horizontal collectors will receive less energy than correctly tilted collectors, and fixed south-facing collectors will receive less energy than those that follow the sun across the sky. However, any movable collector will require complex mounting that would add greatly to the initial expense and upkeep, so frequently the fixed collectors make some economic sense.

Weather effect serves to decrease the absorbed insolation. When the sun is lower in the sky, the sun's rays must travel a greater distance through the atmosphere before reaching the earth. This tends to reduce the heating effect at the surface since a greater portion of the radiation will be absorbed by the atmosphere than when the sun is high.

So you can now see why we want to measure how high the sun is in the sky and to keep track of its position. The effects of the apparent motion of the sun will appear in the results of other solar energy experiments. The sun's height in the sky, measured in degrees from the horizontal, is called the sun's altitude. The horizontal direction, measured in degrees from the true south line to a point on the surface directly beneath the sun, is called the solar azimuth. This definition differs from that used by surveyors, who consider azimuth as the horizontal angle in degrees clockwise from true north to the vertical projection of the line of sight. See Figure 1-3.

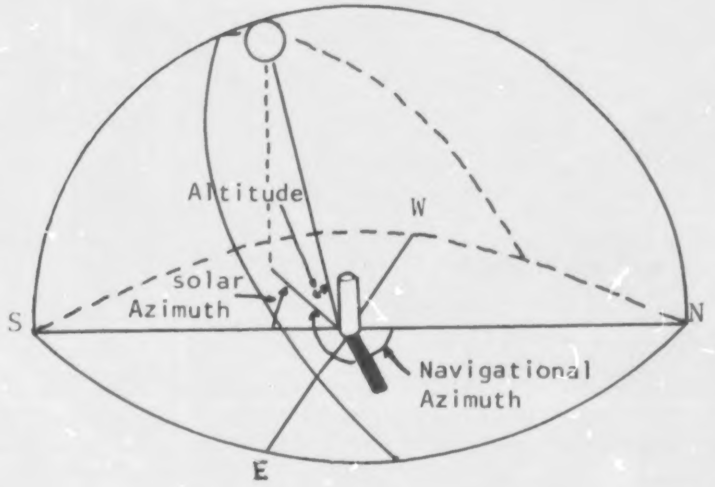


Figure 1-3

Solar azimuth, navigational azimuth, and altitude of the sun.

MATERIALS:

Three-inch finishing nail, 1 square-foot sheet of 1/2 inch plywood, 10 x 10 graph paper, straight edge, protractor, hammer, millimeter scale, carpenter's tri-square, level.

PROCEDURE 1:

Measuring the sun's altitude (vertical angle).

1. Scribe a straight center line across the plywood sheet and drive the finishing nail vertically into the plywood on this line near one end. Check the vertical position of the nail, using a square or right triangle.
2. At 12 o'clock noon, standard time, align the plywood on a level surface so that the nail is toward the south and so that the nail's shadow falls on the scribed line. The scribed line will than be in a nearly north-south direction. Fasten the plywood to its support and make sure all the measurements you make throughout this experiment are taken with this same orientation.

For a more precise determination of a true north-south line, make a four-minute correction to your noon (clock time) for each degree of longitude difference between your observation position and the center of your time zone. For example, if your longitude is 78° west, the sun would cross your meridian (north-south line) 12 minutes later than it did the 75th meridian, which is the center of the eastern time zone. If your longitude is 73° west, the correction is - 8 minutes, and the sun would be on your meridian at 11:52 o'clock. In addition, corrections could be made for the fact that the sun is sometimes ahead and sometimes behind the clock depending on where the earth is in its revolution around the sun (due to changing speed). This latter correction could amount to 15 minutes between local solar noon and 12 noon standard time. The equation of time indicates the appropriate correction (Fig. 1-4). Correction for daylight saving time should be made, too.

A simpler experimental method would be to note the alignment of the shadow when it is shortest. It would then fall on your meridian and the time would be local solar noon.

3. By measuring the height of the protruding nail and the length of the nail's shadow, using the millimeter scale, you will have two measurements that can tell you the sun's altitude at that time.

The altitude is the angle between the horizontal surface and the line of sight to the sun. A line connecting the top of the nail and the tip of the shadow will point directly to the sun and form a right triangle with the nail and shadow. The angle it makes with the horizontal board is the altitude of the sun. From simple trigonometry, you can see that the tangent of this angle is equal to the height of the nail (opposite side) divided by the shadow length (adjacent side). By making this computation and referring to trigonometry tables, you can obtain the angle. An equally valid way to do it would be to construct two perpendicular lines, measure off the length of the shadow on one line, the height of the nail on the other, connect the ends of the lines with a third line (the hypotenuse of the right triangle), and use a protractor to measure the altitude, directly from this plot. The angle between the hypotenuse and the shadow length is the altitude of the sun in degrees.

4. By making measurements at 9 A.M., noon, and 3 P.M. (or at other hours if you wish) on or about the 21st day of each month, you will have a good yearly record of the sun's altitude on days coinciding with the solstices and equinoxes.

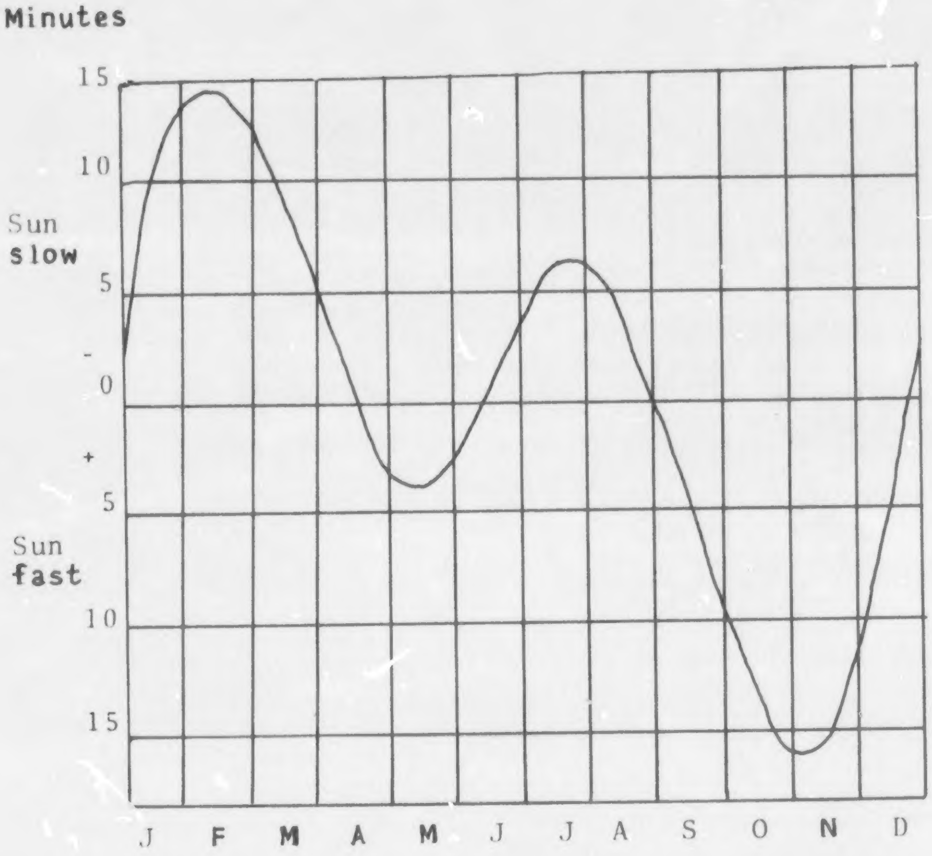


Figure 1-4

Equation of time throughout the year. (After E.A. Fath, Elements of Astronomy, McGraw-Hill, 1934.)

PROCEDURE 2:

Measuring the azimuth (horizontal angle).

1. Every time you measure the length of the shadow for your altitude measurements, measure the angle that the shadow makes with the scribed north-south line. This shadow angle is used to determine the solar azimuth. You can see from Figure 1-3 that this angle is the vertical angle of the solar azimuth and hence is equal to it.

2. It would be instructive for you to actually construct these lines on plain or graph paper. Draw a line representing your meridian. Draw another line intersecting this at the shadow angle that you measured. The intersection of these lines represents the position on the earth from which you made your observations. Note that the shadow itself is a horizontal projection of a part of the sight line onto the surface.

3. Extend this shadow line through the observing point toward the sun's position. This extension is the horizontal projection of the sight line to the sun, and the angle it makes with your meridian is the solar azimuth.

4. You will note that the shadow falls to the west of your meridian in the morning when the sun is in the eastern sky. There will be a corresponding sun-shadow position in the afternoon making the same angle with the north-south line. Thus, solar azimuths have two corresponding sun positions each day. For a 10° azimuth, there is a morning and afternoon position. Disregarding weather and atmospheric conditions, the insolation characteristics at your location in the afternoon will be a mirror image of those found in the morning. Record the altitude, date, and time of day for each observation.

5. On the equinoxes, you will observe that the sun rises due east and sets due west of your position. At these times the solar azimuths are 90°. Between the spring and autumn equinoxes, the early morning and late afternoon shadows fall south of an east-west line since the sun rises and sets north of the east-west line. The solar azimuth is measured relative to the north part of the north-south line at these times. Thus, you can see the need to make careful records of which reference lines you use for your azimuth determinations.

The azimuth system used generally in the sciences, as well as for navigation and military purposes, numbers the degrees clockwise from 0° at the north point through a full circle of 360°. Here, no letters are needed and no numbers are repeated. Also, the addition and subtraction of azimuth angles are quite simple. While this system presents fewer difficulties in this way, the symmetry of azimuth angles about the north-south line in the morning and afternoon is not so obvious. Most solar energy references do not use this navigational system for this reason.

RESULTS:

1. Plot the values of altitudes you obtained versus the time of day for each month on a single graph. A family of curves will be obtained that will show the variations in the altitude of the sun that occur daily and yearly at your location.
2. A similar family of curves may be made for your solar azimuth data.
3. A third curve of shadow length versus altitude of the sun would give you a nice calibration curve for your instrument for determining the altitude directly from your shadow measurement.

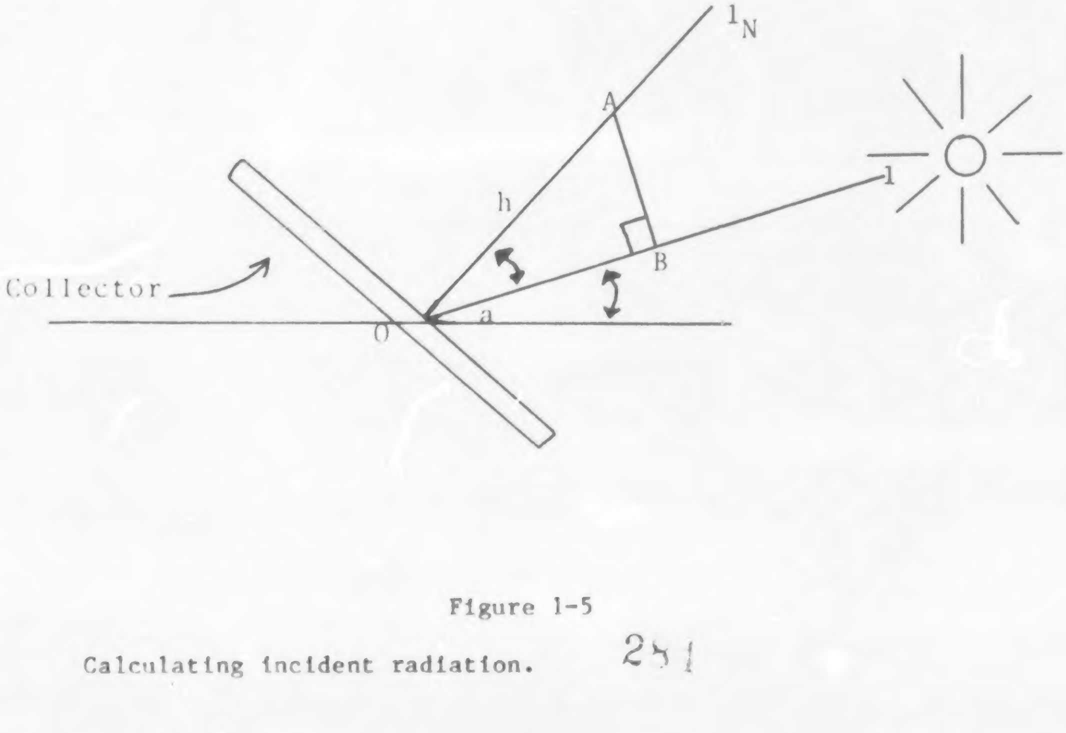


Figure 1-5

Calculating incident radiation.

GEOMETRIC ANALYSIS:

Let the magnitude of the incident radiation I_c striking the collector equal OB when the sun is in line with OB. If the sun were in line with OA or perpendicular to the collector, the angle of incidence θ would be zero and the radiation striking the collector would be at a maximum. With respect to OB it would be OA.

Therefore, the incident radiation actually striking the collector would be the maximum radiation I_N reduced by the ratio $\frac{OB}{OA}$. Or, $I_c = I_N \cdot \frac{OB}{OA}$.

In trigonometry, we translate geometrical relationships into the characteristics of angles. With respect to angle θ, OA is the hypotenuse of a right triangle and OB is the side adjacent to the angle θ. The ratio of adjacent side to hypotenuse, or $\frac{a}{h}$ is called the cosine of θ. Therefore, $I_c = I_N$ x cosine of θ. We write this $I_c = I_N \cos\theta$.

1. The direct or normal rays of the sun form an angle of 90^o with a receiving surface. It is these rays that put energy on the surface in greatest concentration, and hence have the greatest heating effect. The angle of incidence of these rays is zero since, by convention, incident angles are measured with respect to a line parallel to the sun's rays and perpendicular to the surface at the point of incidence. From this experiment, can you determine the relationship between the altitude of the sun and the angle of incidence of the sun's rays? Note that as the altitude increases, the angle of incidence decreases, and the heating effect increases.
2. How does the shadow length vary during the day? During the year? Why?
3. How many degrees does the shadow length sweep across the board per hour? Why? Try to measure this.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

Semester Hours Credit: 3
Lecture: 1
Lab: 4

Project Director: Charles G. Orsak, Jr.

Prime Author: Everet W. Bolin

Contributing Authors: Alan Boyd
Bob Takacs
Norman Abell

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Introduction:

The Materials, Materials Handling and Manufacturing Processes course contains subject matter and skills related to six trades. It would not be possible, in the time alloted for this course, to train craftsmen in all, or any, of these trades.

The intent of this course is to give the student some training in the more basic skills and introduce them to the tools, materials and techniques used in many of the remaining skills of each trade area presented. The depth of coverage and extent of details must be left to the discretion of the instructor of the course. Printed materials, in the form of student handouts, will conserve time in many subject areas, therefore leaving more time for classroom/laboratory instruction in those areas requiring more time.

Course Description:

This course introduces the materials, handling procedures, and manufacturing processes that are utilized in the Solar Industry. It will include the basics of plumbing, sheet metal, carpentry, roofing, glazing, concrete pouring, soldering, welding, and other techniques as they are related to the construction of a Solar system. Compatibility and problems encountered with different materials will be explored.

Course Prerequisites:

Algebra

Course Objectives:

Upon completion of this course the student should have developed the basic skills necessary to:

(1) Work safely with the materials and tools common to solar systems.

(2) Select system materials that are physically and chemically compatible.

(3) Satisfactorily complete basic solar construction projects using correct manufacturing techniques.

MATERIALS, MATERIALS HANDLING AND FABRICATION PROCESSES

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MODULE: GENERAL SHOP SAFETY

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify safety hazards that relate to shop safety, tools, materials, and handling of these materials.

(2) Make appropriate decisions that would minimize potential accidents.

RATIONALE:

Construction, installation, diagnosis, and maintenance of operational solar systems require the use of many hand tools, power tools, materials, shop tools, and fabrication processes/techniques that are potentially hazardous. Awareness of applicable safety measures are essential to the prevention of accidents which may result in personal injury, lost time and/or equipment damage. Accident prevention does pay.

REFERENCES:

(1) Red Cross film - "The Pulse of Life".

(2) USAF Study Guide - "Safety" (AFS 54, 55 and 56)

(3) OSHA Guidelines

UNIT TITLES:

(1) Introduction to Working Safety
(2) General Safety Practices
(3) Personal Safety Hazards
(4) Electrical Safety
(5) Fire Safety
(6) Hand Tool/Power Tool Safety
(7) Mechanical Safety
(8) Chemical Safety
(9) Welding/Soldering Safety
(10) Protective Equipment and Clothing

VOCABULARY:

Safety Classifications:

Electrical
Mechanical
Liquid (acids, refrigerants)
Housekeeping
Hand Tools
Power Tools
Fire
Welding/Soldering
Chemicals
Ventilation
Personal

Unit 1. Introduction to Working Safety - Discuss
  - A. The purpose of safety regulations
  - B. "Is there a safer way to do the job?"
  - C. Define the term accident

Reference 2, Section 54, 55 and 56, OSHA Guide - Applicable Sections

Unit 2. General Safety Practices - Discuss and Describe
  - A. Housekeeping - oil spills, oily rags, tools, materials, etc.
  - B. Horseplay
  - C. Ventilation
  - D. Lighting
  - E. Scaffolds
  - F. Storage racks, stored materials
  - G. Lifting
  - H. Ropes, chains, cables, cords, and hoses
  - I. Scrap material
  - J. Safety check list for equipment
  - K. Safety inspection and reports

Unit 3. Personal Safety Hazards - Demonstrate
  - A. Clothing and protective clothing
  - B. Rings, watches, bracelets, etc.
  - C. Hair, beard
  - D. Shoes

Reference 1, (show film)
Reference 2, Section 54, 55 and 56, OSHA Guide - Applicable Sections

Unit 4. Electrical Safety - Discuss and Describe
  - A. Current that kills - electrical shock
  - B. Power cords
  - C. Disconnects and locks (tags)
  - D. Ground wire
  - E. Electrical equipment maintenance
  - F. Portable electric tools
  - G. Clothing - rings, watches, zippers, metal buttons, etc.
  - H. High voltage warning signs
  - I. First-aid for shock - C.P.R.

Reference 2, Section 54, 55 and 56, OSHA Guide - Applicable Sections	Unit 5. Fire Safety - Describe and Demonstrate A. Fire prevention B. Periodic inspection for fire hazards C. Flammable materials - handling and storage D. Fire extinguisher classification - examples E. Use of portable fire extinguishers
Reference 2, Sections 54, 55 and 56, OSHA Guide - Applicable Sections Reference 2, Section 54, 55 and 56, Safety tips for safe use, provided by manufacturer of power tools, OSHA Guide - Applicable Sections	Unit 6. Hand Tools/Power Tools Safety A. Hand Tools - Dangers of improper use of hammers, hammer handles, chisels, punches, drills, cutting tools, files, rasps, end wrenches, sockets, screwdrivers, pliers, pry bars B. Power Tools - Dangers of improper use of electrical power cords, ground wires, use of vises, clamps, portable drills, circular saws, table saws, nail and staple machines, pneumatic tools
	Unit 7. Mechanical - Demonstrate A. Guards for moving parts (belts, chains, flywheels, etc.) B. Inspection for wear which could be hazardous C. Ladders, lifts, metal shears, brakes, air compressors, compressed gases
OSHA Guide - Applicable Sections	Unit 8. Chemicals - Discuss and Describe Safe Handling Procedures A. Acids B. Alkalines C. Refrigerants D. High and low temperature materials E. Toxic chemicals F. Special handling procedures
Reference 2, Sections 54, 55, and 56 OSHA Guide	Unit 9. Welding/Soldering - Discuss A. High pressure cylinders B. Regulators and hoses

C. Torches, tips, and flashback
D. Environmental caution around flammable or explosive material
E. Danger is using oxygen
F. Electrical shock-arc welding
G. Storage problems
H. Faulty equipment hazard
I. Placement of fire extinguishers
J. Protective equipment and clothing
K. Helmets, shields, and filters

Reference 2, Sections 54, 55 and 56, OSHA Guide - Applicable Sections

Unit 10. Protective Equipment and Clothing - Demonstrate (if possible)
A. Safety Showers
B. Eyewash fountains
C. Earplugs
D. Eye and face protection
E. Safety hats
F. Gloves
G. Safety shoes
H. Machine protective equipment

STUDENT ACTIVITY	Assignment:
Exercise	Complete safety test and sign test as evidence of completion of Safety Module.
INSTRUCTOR ACTIVITY Field Exercise	Set up a field trip to a construction site or campus shop laboratory and:
Exercise I	(1) Identify and list observed, actual or potentially unsafe conditions or working practices. (2) Make recommendations for action; indicate what would eliminate the unsafe conditions/practices.
INSTRUCTOR ACTIVITY	Make Solar Lab available for Safety Examination by students.
STUDENT ACTIVITY Exercise II	Inspect the Solar laboratory and identify conditions, equipment, or materials that could be hazardous unless caution is exercised.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Use common measuring devices for computations.

(2) Convert English to metric units.

(3) Perform measuring tasks and computations with acceptable accuracy.

RATIONALE:

Measuring devices are very important to the success of the solar technician. Most solar applications require many activities where precision measurement is extremely important. The very nature of the solar industry dictates that many of the measurements will be given in metric units. Therefore, it is also critical that the student be able to convert from English units to metric units and vice versa.

REFERENCES:

(1) Tippens, Paul E., Applied Physics, McGraw-Hill Book Company, New York, 1978.

(2) White, Warren T. and others, Machine Tools and Machine Practices, Vol. I, John Wiley and Sons, New York, 1977.

(3) L.S. Starret Company, Athol, Mass., Demonstration Tools.

(4) Lufkin Tools Company, Cooper-Group, Apex, N. Carolina, Demonstration Tools.

(5) Readers' Digest Association, Readers' Digest Complete Do-It-Yourself Manual, Pleasantville, New York, 1973.

UNIT TITLES:

(1) Units of Measurement

(2) Linear Rules

(3) Comparison Tools

VOCABULARY:

Steel Rules

Micrometers - Inside and Outside

Vernier Calipers

English to Metric Conversion Units

Area Measurements

Flexible Measuring Tapes

Calipers

Depth Gauge

Gauge Blocks

Volumetric Measurements

Reference 1, pp. 5-9 Reference 2, pp. 141-143 Printed hand-out on English to Metric conversion	Unit 1. Discuss Units of Measurement A. History from inception to present B. English units - yard, foot, inch, mile, ton C. Metric units - meter, millimeter, kilometer, gram, kilogram, liter D. English to metric conversion factors
Reference 2, pp. 147-156 Reference 5, Section 1 Overhead transparency of linear rule showing resolution. Pass rules to students for clarification (flexible rules are better for this purpose)	Unit 2. Linear rules - demonstrate their use A. Wood rules - rigid and folding B. Steel rules - rigid and flexible C. Flexible tapes - fabric and steel D. Resolution - demonstrate tolerance of measurement
STUDENT ACTIVITY Exercise	Assignment: Given pieces of tubing (various lengths) and steel flexible tapes, the student should: (1) Measure and record the lengths in English units. (2) Convert the English units to metric units.
Reference 2, pp. 157-246 Graphic illustrations of these tools with names will aid in visual identification. Line drawings or pictures can also be utilized. Reference 3 and 4 for demonstration tools	Unit 3. Comparison Tools A. Micrometers - outside, inside and length B. Calipers - spring, outside, inside, vernier C. Parallel blocks, gauge blocks D. Gauges - telescoping, radius, hole gauges, feeler gauges E. Dial indicators

STUDENT ACTIVITY

Laboratory Tasks:

As you progress in this course, measurement skills are essential to success. Due to the highly technical nature of the Solar Technology Program, many of the measurements, dimensions, and values are given in metric units which must be converted to English units unless you have metric measuring tools.

The purpose of this activity is to reinforce and insure that you have those skills. A course project will begin shortly which will require the use of measurements and measuring devices.

LAB EXERCISE I

Lab Materials and Tools:

Pieces of copper tubing, 6" long - 3/8" O.D., 1/2" O.D., and 5/8" O.D., 0-1 micrometer, flexible steel tape, small inside calipers or hole gauge set.

Lab Procedure:

Complete the following for each piece of tubing:

(1) Measure and record the length in English units.
(2) Measure and record the O.D. in English units.
(3) Measure and record the I.D. in English units.
(4) Calculate the volume and the wall thickness in English units.
(5) Repeat step 1 thru 4 and record the results in metric units.
(6) Retain the data and the pieces of tubing since they will be used in the Plumbing Module.

LAB EXERCISE II

Until you become very familiar with fasteners that are length and diameter critical, you may need to measure them to be sure of the sizes. This task will assist you in becoming proficient at selecting the correct, specified fasteners (Next Module).

Lab Materials and Tools:

A variety of No. 10, 1/4" O.D., 3/8" O.D. bolts of different lengths (bolts of 1 1/2" or more in length are more difficult to guess the length), flexible steel tape and 0-1 micrometer.

Lab Procedure:

(1) Measure and record the outside diameter of two or more of each size bolt (threaded portion).
  a. Analyze the results - why are they smaller than the indicated number of fractional size?
  b. What size hole would be required to provide clearance for the bolts?

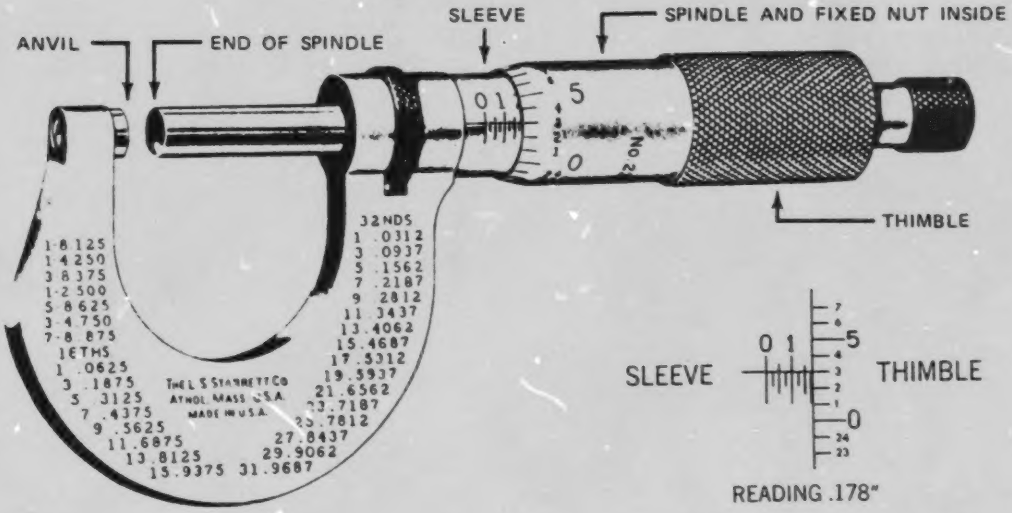
(2) Measure and record the length of the bolts from Step 1.

(3) Convert the measurements from Step 1 and 2 from English to metric units.

NOTE: You will find the skills acquired in this exercise very useful in the following module: Fasteners.

INSTRUCTIONS FOR READING A CRAFTSMAN MICROMETER

FIRST - Read the barrel including the last visible line - THEN add the amount shown on the thimble. EXAMPLE: .375 + .010 equals .385.


ANVIL
END OF SPINDLE
SLEEVE
SPINDLE AND FIXED NUT INSIDE
THIMBLE
0 1
5
0
No 2
1-8 .125
1-4 .250
3-8 .375
1-2 .500
5-8 .625
3-4 .750
7-8 .875
16THS
1 .0625
3 .1875
5 .3125
7 .4375
9 .5625
11 .6875
13 .8125
15 .9375
32NDS
1 .0312
3 .0937
5 .1562
7 .2187
9 .2812
11 .3437
13 .4062
15 .4687
17 .5312
19 .5937
21 .6562
23 .7187
25 .7812
27 .8437
29 .9062
31 .9687
THE L S STARRETT CO
ATHOL MASS U.S.A.
MADE IN U.S.A.
SLEEVE
THIMBLE
0 1
5
0
24
23
READING .178"

The L. S. Starrett Company

A micrometer is a measuring gauge operated by a screw having 40 threads per inch. Therefore one complete revolution of the screw advances one thread exactly or one fortieth of an inch. 1/40" equals 25 thousandths of an inch or .025". Thus each line on the barrel equals .025". The beveled edge of the thimble is divided into 25 equal parts. Each line equals 1/25 of .025" or .001". (one thousandths of an inch). One complete revolution of the thimble therefore equals .025" or one line on the barrel scale.

INSTRUCTIONS FOR READING A MICROMETER TO TEN-THOUSANDTHS OF AN INCH (.0001)

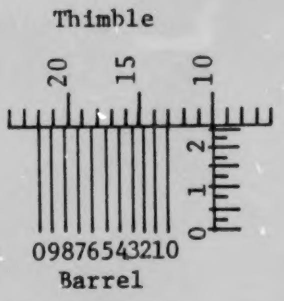


Figure 1

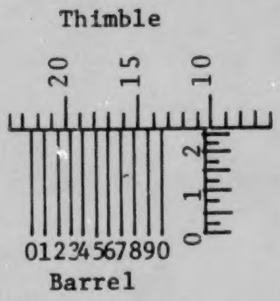
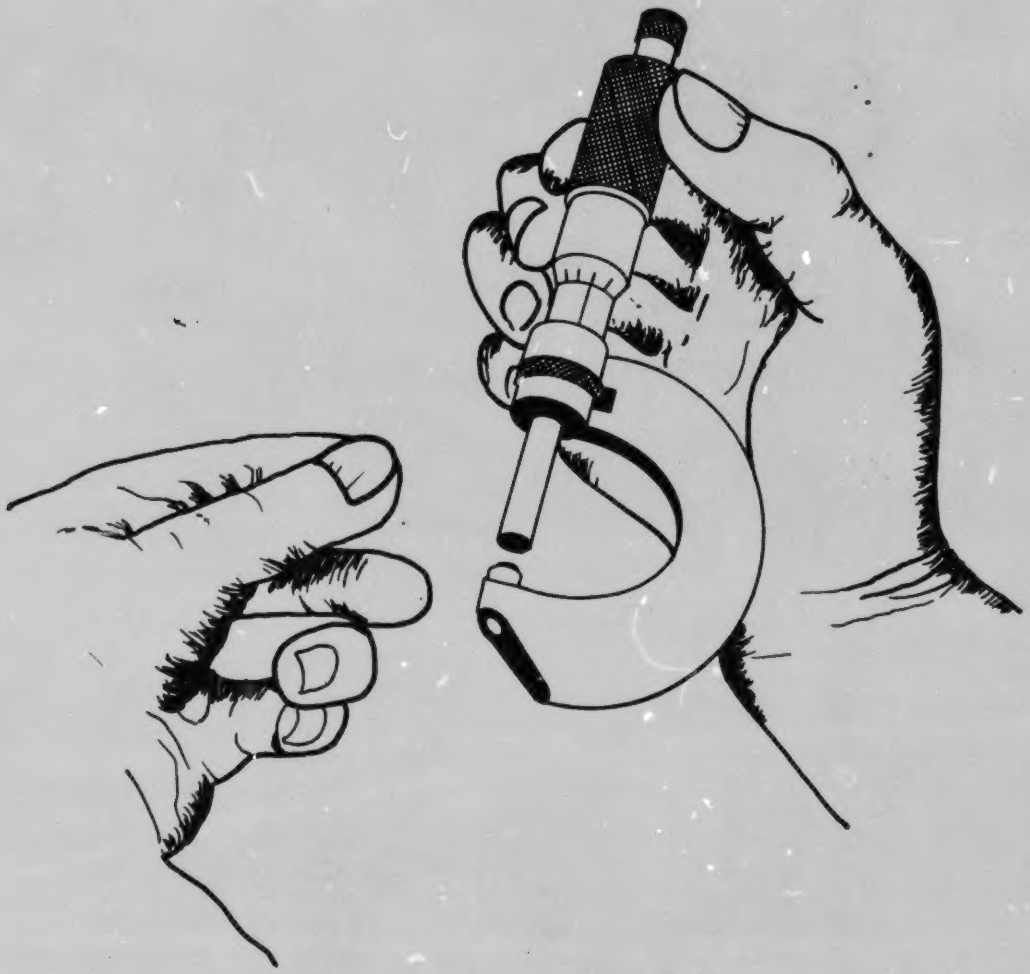


Figure 2

Readings in ten-thousandths of an inch can be obtained by use of a vernier scale. The vernier scale, marked on the barrel, has ten divisions which equal nine divisions on the thimble. Since each graduation on the thimble equals 1/1000 of an inch, then each vernier division is 1/10 of 9/10,000 of an inch. The difference between a thimble is 1/10,000 of an inch. Therefore, when the zero lines of the vernier exactly coincide with thimble lines (Figure 1), the number on the vernier lines is the difference between the vernier line and the next thimble line in ten-thousandths of an inch. Thus when the fifth line on the vernier coincides with a thimble line, the thimble has moved 5/10,000 of an inch.

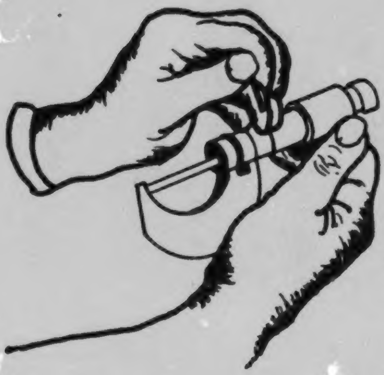
Example: First determine the number of thousandths, as with an ordinary micrometer. Then find a line on the vernier that exactly coincides with a thimble line. By adding the vernier reading to the thousandths reading the actual reading in ten-thousandths of an inch is obtained. The reading shown in Figure 2 is .260 plus .0005 or .2605.

CLEANING CONTACT SURFACES



A handy method to clean the contact surfaces is to close the micrometer lightly on a piece of soft paper. It is then withdrawn. The paper will probably leave fuzz and lint on the surfaces. Blow this out with lung power - not the air hose. Never use compressed air to clean any precision instrument. The high velocity forces abrasive particles into the mechanism as well as away from it.

METHOD OF ADJUSTMENT



With our special form of adjustment, accurate and instantaneous in its action, the problem of adjusting the micrometer becomes a simple matter.

To effect adjustment for wear on measuring surfaces, first clean spindle and anvil contact points, then close the micrometer to the proper feel (1 3/4 lbs. torque pressure or 3 clicks of the ratchet). Secure the micrometer by turning the lock ring to lock the spindle firmly. Grasp the knurled thimble firmly with thumb and forefingers of left hand. With the measuring surfaces in contact, insert the spanner wrench in the hole drilled in micrometer sleeve, holding the spanner between the ball of thumb and forefinger of right hand with the thumb tip resting against the sleeve. The sleeve can then be rotated the amount necessary to make the desired correction and the adjustment should be tested with the micrometer set at zero, taking precaution that there is NO OIL OR DUST ON ANVIL AND SPINDLE SURFACES.

CAUTION

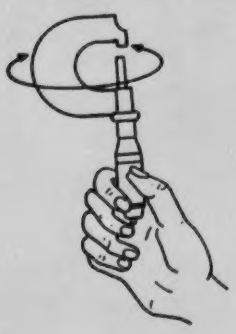
Before leaving the factory, micrometers are carefully and rigidly inspected, comparison being made with the most accurate gauges obtainable, assuring all micrometers of meeting all requirements outlined in Federal Specifications.

For best satisfaction, we recommend that adjustments in tension and setting be made for wear only. The presence of foreign matter on spindle or anvil not visible to the human eye is liable to mislead the user in thinking that the micrometer is out of adjustment. Therefore, make sure that measuring surfaces are clean; secondly, be equally positive that the standard of comparison is correct. Micrometer checking gauge blocks and optical parallels are available on the market primarily for checking a micrometer for lead error and parallelism.

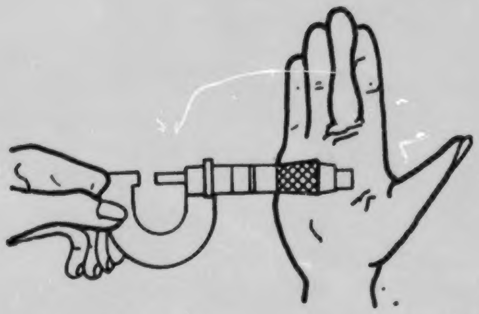
IF **SPINDLE** IS REMOVED FOR CLEANING, DO NOT TOUCH LOCK RING!

DO NOT USE **ELECTRICAL** MARKING PENCIL ON MEASURING INSTRUMENTS

CARE OF MICROMETER



DON'T DO THIS



DO THIS

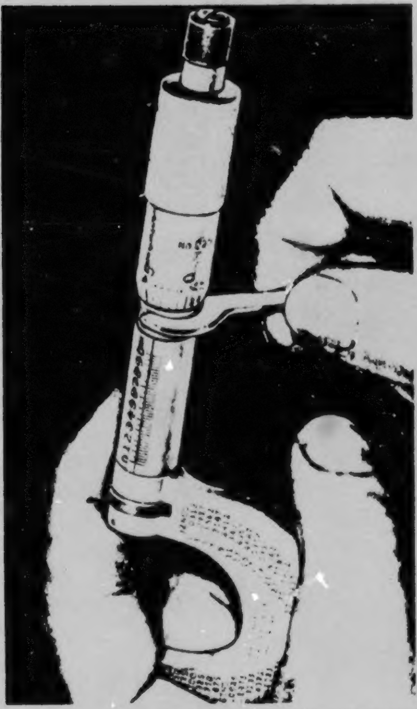
CLOSING THE MICROMETER ON FLAT PARTS

The proper way to approach the part size is before placing the micrometer on the part bring it to nearly the desired opening. Do this by rolling the thimble along your hand or arm - not by twirling. When placing the micrometer onto the reference plane of the part, hold it firmly in place with one hand. Use the feel of stability (no rock) to show when the axis of the micrometer is perpendicular to the reference plane. Rapidly close the micrometer using the ratchet until the spindle is nearly on the measured plane of the part. This usually can be determined visually. If you hit the part before expected, back off slightly and then slowly and gently close the spindle until the ratchet stop disengages one click.

Note that this procedure requires two hands. If the micrometer is handled with only one hand, the ratchet stop cannot be reached, and reliability will suffer. It works out fine for any part that is large enough to support itself without moving around during measurement. It is awkward for small parts.

Some people purchase micrometers without ratchet stops. Don't be one of them. The micrometer is a contact instrument. That means that there must be positive contact between the part and the instrument. And the amount of contact (all-important feel) is up to the user. When you are attempting to measure one-mil (0.001 inch.) reliably - the same true reading time after time - almost imperceptible differences in gauging force can be very important. Because human beings vary so widely this is a source of serious errors in measurement. The "six gun" of the West owed its importance to much the same reason. It was known as the "great equalizer" because the big bully and the undersized whelp were equally persuasive with its help. The modern-day "equalizer" is the ratchet on the trusty mike.

Setting Instructions For
MANDREL MICROMETERS



Courtesy The L. S. Starrett Company

Removing the play in the spindle screw threads

Resetting the accuracy of the micrometer

The over-all distance between spindle and anvil on the mandrel type micrometer is set at the mandrel and shown above.

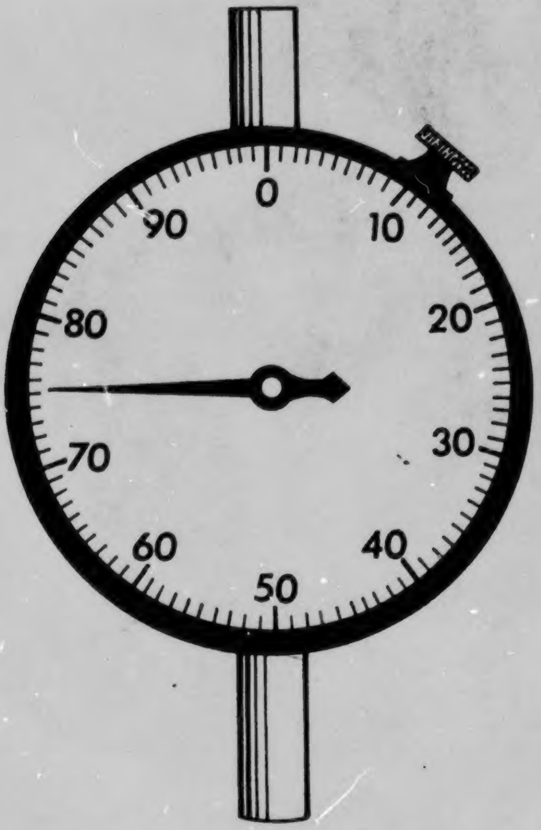
1. First zero the micrometer thimble on the barrel. If necessary, adjust thimble on spindle, so that desired amount of the first barrel graduation shows.

2. Loosen locknut, loosen setscrew in shoulder nut, screw mandrel in or out of shoulder nut, (one complete turn of shoulder nut on mandrel equals approximately .025"), desired distance to get correct distance between spindle and mandrel. Tighten setscrew into shoulder nut and tighten locknut. Check over-all distance between spindle and mandrel several times after complete adjustment.

If necessary readjust to get desired distance.

Always insure that numbers on mandrel coincide completely with numbers on frame and are in line with the numbers on the frame as shown above.

DIAL INDICATOR CARE AND HANDLING



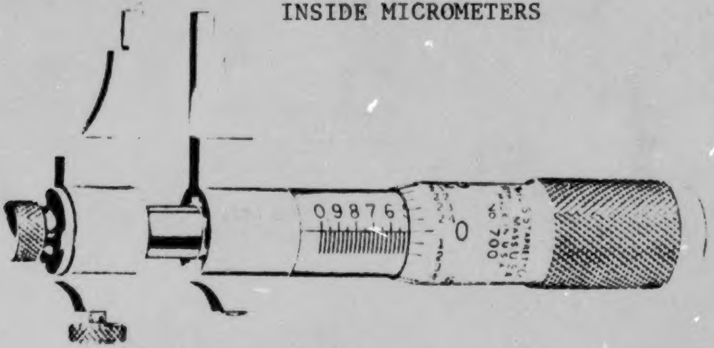
The spindle of a Dial Indicator is intended to work dry. It is important that it is never oiled or greased. The spindle is made a very close fit in its bearings and even thin oil will collect dirt which will cause the Indicator to stick.

If the Indicator is used in conditions where oil or foreign matter would inevitably come in contact with the spindle, it is good practice to clean the spindle regularly.

A sticking spindle can quickly be cured by wiping at the lower end, compressing it and then wiping at the top end (after removing the top cover if fitted). Repeat this procedure if necessary until stickiness disappears.

While the Dial Indicator is of simple design and ruggedly constructed, it is obviously a precision instrument and should be treated with respect if it is to retain its accuracy and continue to give trouble free service.

INSIDE MICROMETERS



For inside measurements larger than 40mm (1½ in. for inch-designed instruments), inside micrometers are used. The inside micrometer set consists of a micrometer head, having a range of 25mm(½ in. or 1 in. for inch tools), several extension rods of different lengths which may be inserted into the head, and a ½ in. spacing collar. These sets cover a range from 40 to 1000mm or from 1½ in. to over 100 in. for inch tools. Sets that are used for the larger ranges generally have hollow tubes, rather than rods, for greater rigidity.

The inside micrometer is read in the same manner as the standard micrometer. Since there is no locking nut on the inside micrometer, the thimble nut is adjusted to a tighter fit on the spindle thread to prevent a change in the setting while it is being removed from the hole.

To use an inside micrometer caliper,

1. Adjust the jaws to slightly less than the diameter to be measured.

2. Hold the fixed jaw against one side of the hole, and adjust the moveable jaw until the proper "feel" is obtained. NOTE: Move the moveable jaw back and forth to ensure that the measurement taken is across the diameter.

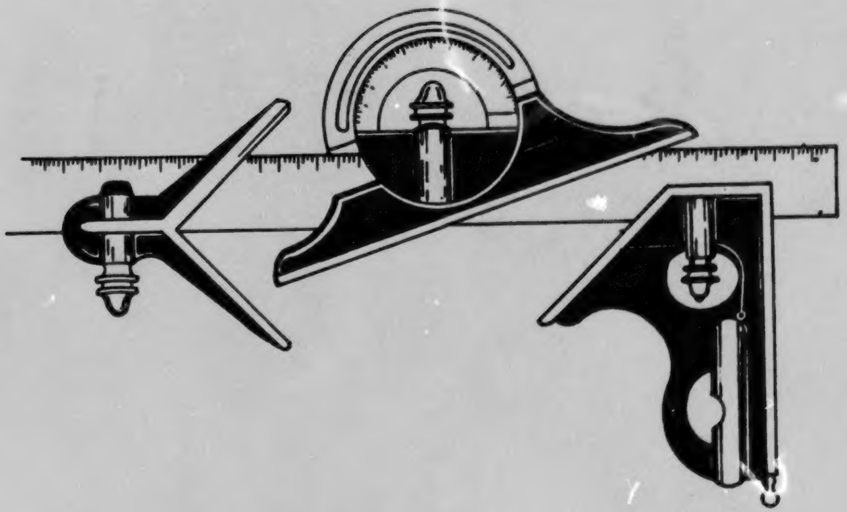
3. Set the lock nut, remove the instrument, and check the reading.

If through wear or other reasons one or more of the measuring rods in out of tolerance, it must be reset by using the adjustment nuts on the top of the rod.

The spindle friction feel may be adjusted by means of the wear nut on the end of the micrometer barrel.

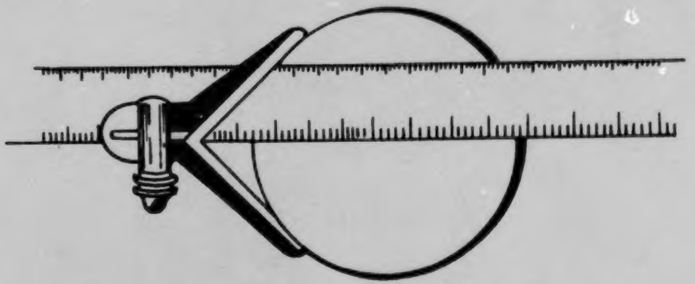
When installing a new set of measuring rods or after relapping the rods, the thimble should be first set to zero with most of the zero graduation line showing on the barrel. This setting may be achieved by rotating the micrometer thimble sleeve relative to the thimble body by means of the spanner wrench provided, until the correct amount of barrel line shows when the thimble is at zero. The measuring rods should then be set to the correct respective length.

COMBINATION SQUARE SET



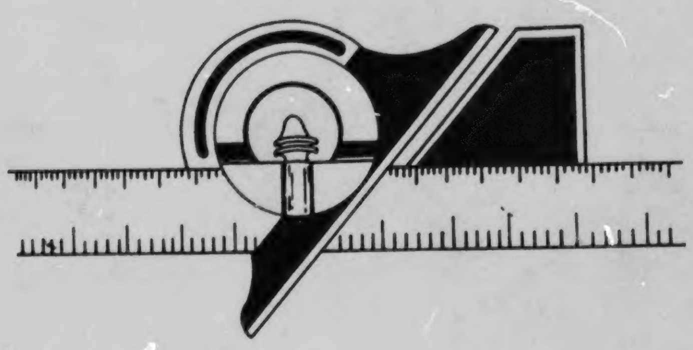
The Combination Square Set consists of a blade, protractor, center head, and a square head. This instrument combines all features of the center head, protractor, and square head. This versatile tool allows you to use one tool for layout assembly, inspection, and many other uses.

CENTER HEAD



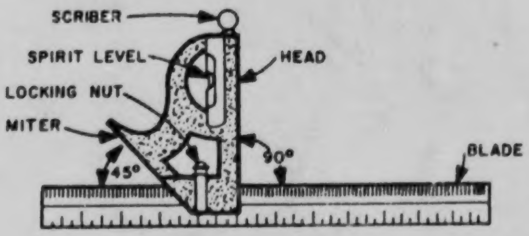
The Center Head speeds the measurement of diameters and improves reliability. For layout purposes the Center Head provides one of the most satisfactory methods for finding the centers of shafts.

PROTRACTOR HEAD



The Protractor Head with sliding blade forms a versatile instrument for the measurement of angles. The Protractor Head is easily interchanged with the square head, and provides a convenient means of measuring Angles as close as 1 degree. Added advantages are its rugged construction and ease of use.

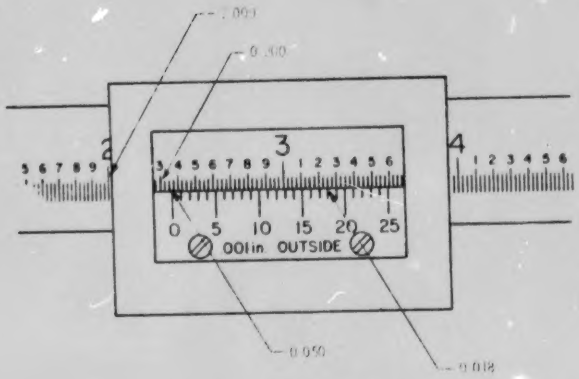
COMBINATION SQUARE



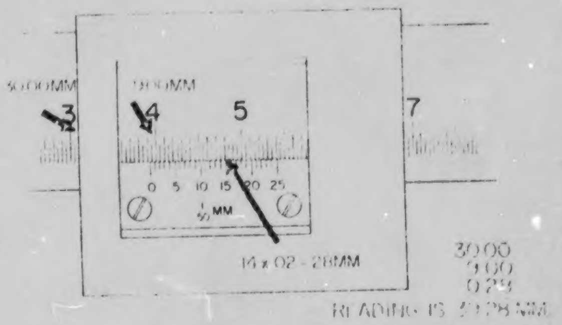
COMBINATION SQUARE

This tool can be used as both a try and miter square, the adjustable blade giving accurate measurement in all positions.

INSTRUCTIONS FOR READING
THE VERNIER SCALE



Vernier scale. To be used as example for reading.



The same principles are used in reading Vernier tools in metric measure as thqse in English measure except that the readings are obtained in 1/50 of a millimetre or 0.02 mm. To read the above illustration, note that the Vernier has been moved to the right of 30.00 plus 9.00 and the fourteenth line on the Vernier scale coincides with a line on the bar. Therefore, 14 x 0.02 or 0.28 mm are to be added to the 39.00 mm reading and the total reading is 39.28 millimetres.

On the English vernier caliper scale the beam is calibrated in fortieths, or .025 of an inch. Every fourth division representing a tenth, or .100 of an inch, is numbered. The vernier plate is divided into 25 parts and numbered 0, 5, 10, 15, 20, 25. The vernier "shift" is thus .001 inch for each graduation of the vernier.

To read the tool, note how many inches, tenths (or .100), and fortieths (or .025) the 0 mark on the vernier is from the 0 mark on the beam; then note the number of divisions on the vernier scale from its 0 to a line which exactly coincides with a line on the beam. The reading on your vernier scale is your thousandths reading. All readings are then summed up to give the total caliper measurement to the nearest .001 of an inch.

On the Metric vernier caliper scale the beam is calibrated in millimeters, or .100 of a centimeter. Every 10th division representing centimeter is numbered. The vernier plate is divided into 20 parts and numbered 0, 2, 4, 6, 8, 10. The vernier "shift" is thus .005 of a centimeter, or a twentieth of a millimeter, for each graduation of the vernier.

To read the tool, note how many centimeters and millimeters (or .100) the 0 mark on the vernier is from the 0 mark on the beam; then note the number of divisions on the vernier from its 0 to a line which exactly coincides with a line on the beam. This number of divisions on the vernier is multiplied by .005 and all the readings summed up to give the total caliper measurement to the nearest .005 of a centimeter.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify common fasteners used in Solar applications.

(2) Select the most appropriate fastener(s) for a given construction task.

(3) Demonstrate skills in the use of fastening tools and fasteners, including appropriate safety precautions.

(4) Identify hand and power tools used in Solar installations.

(5) Select appropriate hand and power tools for a given Solar construction task.

RATIONALE:

Many of the construction devices and assemblies used in the installation of solar systems are dependent upon a variety of fasteners and tools. This module will give the student a basic knowledge of most of the kinds of fasteners and tools used in solar installations and construction techniques. The use of fasteners and tools can also present a potential safety hazard, specifically in the area of automatic or power tools. It is recommended that the instructor give emphasis toward the safety measures required for these devices.

REFERENCES:

(1) Popular Mechanics, "Master Shop Guide", 1973.

(2) Readers' Digest Association, Readers' Digest Complete Do-It-Yourself Manual, Pleasantville, N.Y., 1973.

(3) Morgan, Alfred P., How To Use Tools, Arco Publishing Co., N.Y., 1973.

(4) Irving, Daniel W., Power Tool Maintenance, McGraw-Hill Book Co., N.Y., 1971.

UNIT TITLES:

(1) Hand Tools

(2) Nails and Staples

(3) Screws and Bolts

(4) Other Common Fasteners

(5) Power Tools

VOCABULARY:

Nails
Wood Screws
Bolts
Washers
Staples
Molly Bolts
Insulation Studs
Wedge Anchors
Metal Framing Connectors
Sheet Metal Scores
Hand Saws
Power Saw
Screwdrivers
Hammers
Routers
Files and Rasps
Tin Snips
Planer
Power Sanders
Levels
Nut Drivers
Carpenters Square
Combination Square
Sheet Metal Screws
Break-Over and Extensions
Grinders
Vises

Nail Guns
Machine Screws
Nuts
Lag Bolts
Toggle Bolts
Lead Anchors
Plastic Anchors
Rivets
Adhesive and Glues
Hole Saws
Hack Saw
Pliers
Braces
Sockets, Ratchets
Planes
End Wrenches
Jointer
Sanding Blocks
Power Drills
Prybars
Drill Bits
Machinist Square
Adhesives and Glues
Adjustable Wrenches
Chisels and Punches
Pipe Wrenches

Unit 1. Hand Tools - Identification and Use

A. Hammers - claw, ball pain and soft
B. Screwdrivers - filister and Phillip
C. Pliers - slip joint, channel lock, vise grip, long nose, diagonal cutting, edge cutting, linemans
D. End wrenches - open, box, combination
E. Socket sets - sockets, ratchets, extension break-over bars
F. Nut drivers
G. Chisels - metal, wood
H. Punches - pin, prick, center
I. Hand saws - rip, cross-cut, keyhole, mitre
J. Metal drill bits - fractional sizes, letter sizes, number sizes
K. Wood bits and braces
L. Tin snips - aviation, combination
M. Hole saws - shell, butterfly
N. Pry bars and nail bars
O. Files and rasps - flat bastard, triangular, half round, round, single cut, double cut
P. Planers and sanding blocks
Q. Levels - horizontal, vertical, string combination
R. Adjustable wrenches - end, pipe
S. Vises - bench, pipe, drill press
T. Clamps - c-clamps, pipe clamps, hand screw clamps, spring clamps

Reference 1, Section 1
Reference 2, See Index

Provide a printed hand-out that includes sketches and names of hand tools. A 4' X 8' sheet of plywood with these tools mounted and identified would reinforce the learning process.

Reference 2, Section 3

Full scale printed handout on nails and staple sizes, or examples of each type and size bonded to a display board with type and size identified.

Unit 2. Nails and Staples - Identification and Use

A. Material - steel, brass, aluminum
B. Staples - shape and length of staple
C. Finish - plated and non-plated nails, plastic coated staples
D. Applications - demonstrate use of nails and staples as fasteners

Reference 1, pg. 8
Reference 2, Section 3

Printed hand-out or display board of the most common sizes of each.

Unit 3. Screws and Bolts - Identification and Use

A. Wood screws - materials, sizes, configurations, finish (plating) and appropriate utility
B. Sheet metal screws - materials, sizes, configurations, finish (plating) and appropriate utility
C. Machine Screws - materials, sizes, configurations, finish (plating) and appropriate utility
D. Bolts, nuts and washers - materials, sizes, configurations, finish (plating) and appropriate utility
E. Lag bolts and anchors - materials, sizes, configurations, finish (plating) and appropriate utility
F. Toggle bolts and molly bolts - materials, sizes, configurations, finish (plating) and appropriate utility

NOTE: Instructor should demonstrate the appropriate technique for driving nails and installing screws and bolts. Give example applications of each while demonstrating the uses. Also demonstrate the safe use of powered nail guns and rivet guns.

EMPHASIS ON SAFETY HERE!

Reference 2, Section 3

Graphic illustration or printed hand-out showing these types of fasteners. Pass some around for student examination.

Unit 4. Other Common Fasteners -

- A. Plastic and wedge anchors - sizes, hole size required and applications
- B. Rivets - types, sizes, hole size required, application and installation techniques
- C. Adhesives and glues - materials toxicity, bonding methods, curing time, resistance to environmental degradation
- D. Metal framing connectors post anchors, caps, joist and beam hangers, plywood clips, shear plates

INSTRUCTOR ACTIVITY

Provide a sketch of the assembly, materials, and tools required.

STUDENT ACTIVITY

Laboratory Tasks:

Lab Exercise:

The module following this one will begin the construction of a class/team/individual project. The appropriate selection and use of fasteners will be vital to the success of the project. This task will reinforce the skills required for beginning the project.

Lab Materials and Tools:

16 oz. claw hammer, nails, wood screws, glue, 4 pcs. of 2" x 4" wood 12" long, screwdriver, carpenters square.

Lab Procedures:

1. Place 2 pieces of wood end to end, forming a ninety degree angle.
2. Spread adhesive (glue) on these adjoining surfaces.
3. Drive nails through one piece of wood, into the other, tightening the glue joint.
4. Make certain the assembly remains square (90 degree angle).
5. Repeat steps 1 thru 4 for the other two pieces of wood.
6. Place these two assemblies together, forming a square frame.
7. Repeat step 2 at both unfastened corners.
8. Use screws to fasten each of these two joints, clamping the glue joints for curing.

9. Make sure the final assembly remains square. It may require some adjustment.

10. Have your instructor evaluate your assembly.

Reference 2, Section 2
Reference 4, Part 2

Unit 5. Power Tools - Identification and Use

CAUTION: EMPHASIZE **SAFE USE**

Printed hand-out of these tools with pictures or drawing and identifying names.

A. Power Saws - circular (portable), radial arm, table, band, sabre
B. Power sanders - disc, drum, belt sanders (portable and table), orbital
C. Power drills - portable (variety of chuck capacity and speeds), drill presses
D. Grinders - portable, bench, floor
E. Routers, jointers and planers

STUDENT ACTIVITY

Assignment:

Given line drawings, sketches or pictures of hand tools and power tools from Unit 1 and 2, place the correct name of the tool in the space provided.

INSTRUCTOR ACTIVITY

Demonstration:

Demonstrate the use of the circular saw (portable), 1" diameter spade drill (wood bit) and hammer by cutting a piece of wood; drilling a hole through it using the spade drill and a portable drill motor; and nail it to another piece of wood.

CAUTION: **Emphasize safe** use.

NOTE: These tools are commonly used daily and represent potential safety hazards if not used properly. Because they are so common, they are frequently taken for granted, resulting in personal injury and lost time.

LAB/SHOP

NOTE TO INSTRUCTOR:
You will have to decide how many of these assemblies can be stored for further use in this course and the Collector and Energy Storage course.

Lab/Shop Exercise:

STUDENT ACTIVITY

The student (may be a team project) will build the framework for the roof section of portable and/or scale model collector racks. This project will progress throughout the Materials, Materials Handling course and be used for demonstration/lab exercises in the Collectors and Energy Storage course. The exercise below will produce two each of these frames.

Lab Materials and Tools:

A 4′ x 8′ sheet of 1/2" exterior grade plywood, a portable circular saw, claw hammer, number 8 galvanized common nails, 4 pcs. 2" x 4" x 8" long treated yellow pine, a flexible tape measure and a carpenters square.

Lab Procedures:

1. Layout the sheet of plywood to cut in half - 4′ x 4′ - using the circular saw.
2. Calculate the lengths required to make a 4′ x 4′ square frame (butt nailed) from the 2" x 4" pieces. Double check your calculations. All pieces will not be the same length.
3. Layout the 2" x 4" yellow pine to cut the 8 pcs. required.

4. Using the portable circular saw, cut the 2" x 4" pcs. (8) to length.
5. Nail the framework together, keeping it square, to produce a 4' x 4' + 1/8" frame. You should have two frames from the 8 pcs.
6. Temporarily (using No. 6 duplex nails) nail the 4' x 4' piece of plywood to the frame - (at the corners) for rigidity.

NOTE: Set these assemblies aside. Further work on these will be required as the course proceeds.

MODULE: WELDING

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify arc welding and oxygen/acetylene welding tools, equipment, and materials.

(2) Select the appropriate equipment, techniques, and materials for a welding task.

(3) Demonstrate minimum proficiency in welding flat positions, butt positions, lap positions, and vertical positions.

RATIONALE:

The Solar Technician who possesses basic welding skills is a valuable asset to the employer. These on the job skills can save a lot of time and keep the installation moving on schedule. Welding the system structure, where applicable, can result in a sound, economical system.

REFERENCES:

(1) Giachino, J. W. and others, Welding Technology, American Technical Society, Chicago, 1968.

(2) Houldcroft, P. T., Welding Process Technology, Cambridge University Press, N.Y., 1977.

(3) Giachino, J. W. and others, Welding Skills and Practices, 4th Ed., American Technical Society, Chicago, 1976.

(4) Griffin, Ivan H. and others, Basic Arc Welding, Delmar Publishers, Albany, N.Y., 1977.

(5) Griffin, Ivan H. and others, Basic Oxyacetylene Welding, Delmar Publishers, Albany, N.Y., 1977.

UNIT TITLES:

(1) Welding Equipment
(2) Metallurgy (Properties of Metals)
(3) Common Welding Processes
(4) Set-Up and Operation
(5) Welding Techniques
(6) Cutting Procedures

VOCABULARY:

Electrode Holder
Puddles
Tensile Strength
Lap Joint
Arc Cutting
Carbon Steels
Fillet Weld
Regulators
Non-Ferrous Metals
Multiple Pass Joints
Torch Handle
Fluxes
Welding Rod
Metal properties
Beads
Flame Cutting
Cast Iron
Butt Joint
Welding Symbols
Alloy Steels
Corner Welds
Tips
Brazing
Ground Clamp
Chipping Hammer
Resistance Welding

Reference 1, Chapter 2 Reference 3, Chapter 3	Unit 1. Welding Equipment - Discuss A. Arc welders (portable) - A.C. welders, D.C. welders, single phase welders, ground cable, electrode holder, power supply (current requirements, voltage drops), transformer taps or variable A.C.
Reference 1, Chapter 1 Reference 3, Chapter 22 Reference 5, Units 1-6	B. Oxyacetylene welders - high pressure cylinders (safety, left and right threads, protective caps), regulators (single stage, two stage, diaphragm adjustment, safety), hoses (oxygen hose, acetylene hose), torch handle (valves, filters, flash back arresters check-valves, hose connections), tips (tip selection, tip reamers, filters, position - related to handle).
Reference 4, Unit 1 Reference 3, Chapter 3 Demonstrate appropriate use of the protective equipment. Reference 3	C. Protective equipment - gloves, face mask (hood) and filter, goggles, apron, appropriate clothing and shoes, fire extinguishers, shield requirements, ventilation, cylinders (cap, pressure relief valve, fusible plug).
	D. Welding Accessories - vises, clamps, hammers, gauges, meters, special wrenches, carts, striker.
Reference 1, Chapter 7 Reference 3, Chapter 2	Unit 2. Metallurgy (Properties of Metals) - Discuss A. Ferrous Metals - low carbon steels, medium carbon steels, high carbon steels, alloy steels
	B. Non-ferrous Metals - aluminum, brass, copper
	C. Mechanical properties - stress, strain, elasticity, tensile strength, comprehensive strength, fatigue strength

	D. Chemical properties (optional) - resistance to acids, resistance to plating
Reference 2, Chapter 1 Reference 1, Chapter 1-9	Unit 3. Common Welding Processes - Discuss and Describe A. Fusion B. Electric resistance (spot welding) C. Electric arc - shielded, unshielded D. Brazing and braze-welding
Reference 5, Units 1-8 Demonstrate set-up and operation of welding equipment	Unit 4. Set-Up and Operation - Demonstrate A. Oxyacetylene - cylinder preparation, regulator (hose and torch assembly), tip selection, purging the system, adjusting the flame, work placement
Reference 4, Units 1-8	B. Arc welder - power supply, electrode cable and ground cable, arc shield (curtains), electrode selection, current selection, work placement
Reference 4, Units 5, 10-20 Demonstrate welding techniques by making weld joints. Pass around extra eye protection so students may observe the process and technique.	Unit 5. Welding Techniques - Demonstrate A. Welding symbols B. Arc welding - puddles, beads and fillets, chipping and cleaning, butt welds, lap joint welds, flat welds, vertical welds, tack welds
Reference 5, Unit 9-12 Reference 1, Chapter 11 Demonstrate cutting procedures.	Unit 6. Cutting Procedures A. Cutting heads, cutting charts B. Flame adjustment, oxygen stream, cutting speed, cutting angle C. Cutting patterns from layout

STUDENT ACTIVITY	Assignment: 1. Identify welds and beads that would be performed from welding symbols. 2. Select electrode for tensile strength required and type of weld joint to be made, based upon decision from step 1 above.
Lab Exercise I	Laboratory Tasks:
Laboratory Materials and Tools:	Arc welder, hood, gloves, electrodes, welding bench, shield (curtains), short lengths of angle iron, chipping hammer, and wire brush.
Lab Procedure:	1. Set up arc welder for task. 2. Select appropriate electrodes. 3. Make butt joint and lab joint.
Lab Exercise II	Laboratory Tasks:
Laboratory Materials and Tools:	Oxyacetylene rig, wrench, striker, cutting head, tips, soapstone, and 1 foot of 2" angle iron.
Laboratory Procedures:	1. Assemble welding rig. 2. Attach cutting head. 3. Select and install cutting tip. 4. Layout with soapstone a 4" length of angle iron. 5. Flame cut angle iron. Keep the cut square.

MODULE: CARPENTRY

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe wood materials by type and grade.

(2) Identify wood characteristics and properties.

(3) Select appropriate construction techniques for solar applications.

(4) Select correct tools for solar carpentry tasks.

(5) Construct a scale model solar collector rack.

RATIONALE:

Skills in carpentry are very necessary for the installation of solar systems. Since the student will be using hand tools and power tools in learning the carpentry skills, it is extremely important that the appropriate safety measures be identified. It is not the intent of this module to make the student a skilled carpenter, but to give him/her the necessary training in the basic skills required for the installation of a solar system.

REFERENCES:

(1) Readers' Digest Complete Do-It-Yourself Manual, Readers' Digest Association, Pleasantville, N.Y., 1973.

(2) Capotosts, John, Basic Carpentry, Reston Publishing Co., Reston Va., 1975.

(3) Wagner, Willis H., Modern Carpentry, Goodheart-Willcox Co. Inc., South Holland, Ill., 1976.

(4) Colorado State University, Solar Heating and Cooling of Residential Buildings, U.S. Dept. of Commerce, 1977.

UNIT TITLES:

(1) Wood Construction Materials

(2) Cutting Methods

(3) Construction Fasteners

(4) Carpentry Tools

(5) Common Solar Applications

VOCABULARY:

Lumber Grades
Right Angle Joints
Select
Criss-Cross Joints
Common
Three Way Joints
Hard Wood
Wood Fasteners
Soft Wood
Preservatives
Lumber Sizes
Cornice
Board Feet
Trim
Plank
Rip Cut
Beam
Cross Cut
Framing Square
Plywood
Circular Saw
Mitres Joints
Radial Arm Saw
Dado Joints
Table Saw
Mortise Joints
Band Saw
Dovetail Joints
Claw Hammer
Nail Bar

Reference 2, pg. 79
Reference 3, Unit 4

Sample pieces of these materials, available for student examination, would be helpful.

Unit 1. Wood Construction Materials - Describe and Demonstrate Use

- A. Lumber - types, grades, sizes
- B. Plywood - structural properties, types, sizes, finishes, grades
- C. Particle Board - physical properties, grades, sizes

Reference 1, Section 1
Reference 2, pp. 9, 23-28

Unit 2. Cutting Methods - Describe and Demonstrate

- A. Layout procedures - methods of layout for angles, cutouts, use of chalk line, cut-off, other construction tasks
- B. Cuts - rip, cross, angles, mitred

DEMONSTRATION:

Demonstration of layout procedures and cutting methods and tools utilized in making somewhat complex carpentry tasks.

Examples:

1. Layout and cut compound angle on a 2" x 4" piece of lumber.
2. Layout and cut a 10" diameter hole in a piece of plywood.
3. Layout and cut an oblong hole in a piece of plywood.

Reference 1, Sections 1,2
Reference 3, Unit 1

Unit 3. Carpentry Tools - Demonstrate Use

- A. Layout tools - rafter square, tri-square, combination square, trammel points, carpenters pencil, T-bevel, scratch awl chalk line, dividers
- B. Measuring tools - folding rule, flexible steel tape, long fabric tape
- C. Assembly tools - line level, carpenters level, plumb bob

Reference 3, Chapter 11
Reference 4, Module 6

Unit 4. Common Solar Applications - Describe and Discuss

- A. Collector racks - types and construction methods
- B. Storage facilities - rock storage bins, liquid storage racks, facades
- C. Roof framing - types, rafters, plates, trusses, ridges, gussets, structural considerations for solar applications

Lab Exercise

Lab Materials and Tools: A blueprint (sketch or drawing) of the scale model collector rack, including bill of materials required. Two pieces of 2" x 6" yellow pine (treated) 8 feet long. Number 8 and 16 galvanized box nails, galvanized roofing nails, flexible tape measure (steel), carpenters square, hand saw, claw hammer, portable circular saw and Scale model collector rack begun in the Hand/Power Tools Module.

Lab Procedures:

1. Remove the plywood from the collector rack by removing the duplex nails.
2. Make the heel-cut (birds mouth) in the rafter (simulated) as indicated by the drawing. Lay out the cut and use the hand saw. Be sure the layout is correct.
3. Assemble the bottom frame (simulating the ceiling joints and plates) per drawing, using No. 16 nails. Keep it square.
4. Install plywood sub-roof (roof deck) permanently, using galvanized roofing nails.
5. Cut risers to length and angle indicated by drawing.
6. Install risers using No. 8 galvanized nails.

NOTE: Set this assembly aside. It will be used in future Modules toward final installation of scale model collectors.

MODULE: SHEET METAL

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify common sheet metal tools.

(2) Work safely with sheet metal and associated tools.

(3) Describe sheet metals by type, gauge, and finish.

(4) Construct simple sheet metal patterns.

(5) Construct sheet metal projects such as transition pieces or pitch pans.

RATIONALE:

Sheet metal skills are very useful since it is often necessary to build transition pieces, pitch pans, and flashing as the solar system is installed on the residential site. Every institution may not have all of the equipment identified in this module; however, those basic to the necessary skills are identified.

The sheet metal project identified in this module will be used at a later time in the Collector and Energy Storage course; therefore, it will become a useful project.

REFERENCES:

(1) Meyer, Leo A., Sheet Metal Shop Practice, 4th Ed., American Technical Society, Chicago, 1975.

(2) Budzik, Richard S., Sheet Metal Technology, Bobbs-Merrill, Indianapolis, 1971.

(3) Zinngrabe and Schumacher, Practical Layout for the Sheet Metal Shop, Delmar Publishers, Albany, N.Y., 1975.

UNIT TITLES:

(1) Sheet Metal Safety
(2) Sheet Metal Terminology
(3) Sheet Metal Tools
(4) Sheet Metal Types
(5) Pattern Layout

VOCABULARY:

Scratch Awl
Pattern Layout
Hole Punch
Protractor
Elbows
Hand Brakes
Trammel Points and Bar
Sheet Metal Fasteners
Bench Stake
Center Punch
Steel Tape
Transition Piece
Tin Snips
Divider
Pitch Pans
Files
Prick Punch

Reference 2, Chapter 2	Unit 1. Sheet Metal Safety - Discuss and Describe A. General safety rules - equipment, scrapes and burrs, housekeeping, soldering B. Handling sheet metal - burrs, use gloves when possible, clamps and hoists, safety shoes
Reference 1, pg. 308 (Suggest printed handout)	Unit 2. Sheet Metal Terminology - Discuss and Give Example A. Tool terminology B. Forming terminology C. Finish terminology D. Layout terminology E. Metals terminology
Reference 2, Chapter 2	Unit 3. Sheet Metal Tools - Demonstrate Solar Applications A. Hand tools - scratch awl, prick punch, center punch, dividers, blade protractor, rivet hammer, combination snips, aviation snips, hole punch (hand), grooving, stakes, metal gauge B. Shop tools - squaring shear, notching machine, hole punches, drill press, bending brake, box and pan brake, finger brake
Reference 1, Chapter 4 Reference 2, Chapter 3	Unit 4. Sheet Metal Types - Discuss and Describe Solar Applications A. Hot rolled - properties, gauge sizes and weight, oxides, finishes B. Galvanized - properties, gauge sizes and weight, oxides, finishes C. Stainless steel - types and properties, gauge sizes and weight, oxides, finishes D. Aluminum - types and properties, gauge sizes and weight, oxides, finishes

E. Copper - types and properties, gauge sizes and weights, oxides, finishes

Unit 5. Pattern Layout - Discuss and Describe Solar Sheet Metal Layout

Reference 1, Chapter 7
Reference 2, Chapter 5
Reference 3, pp. 36-83

A. Geometric principles - views and projections, sheet metal drawings (plan and elevation views)
B. Notches - edge, corner, construction
C. Bend lines - edges and hems, flanges, dove tail seams

STUDENT ACTIVITY

Exercises:

Assignment:

Outside of classroom

Physical properties of sheet metal, recognition of tools and tool use, advantage and disadvantages of the various sheet metals are critical to application in the solar industry.

1. From an assortment of sheet metal tools, the student will identify and describe the function of each.
2. List one advantage and one disadvantage of each sheet metal type.
3. Using a physical properties table, calculate the total weight of a 4′ x 8′ sheet of:
   a. Galvanized steel.
   b. Stainless steel.
   c. Copper.

INSTRUCTOR ACTIVITY

Provide sketch, materials and tools.

Lab Exercise I
Laboratory materials and tools:

LAB/SHOP:

Provide aviation snips, soft hammer, sheet stakes, portable drill motor, dividers, prick punch, center punch, twist drills, 12" square of 28 gauge sheet metal, 6" length of 4" diameter round duct and sketch of project.

STUDENT ACTIVITY
Laboratory procedures:

1. Cut hole in center of 12" square sheet metal to match outside diameter of 4" round duct.
2. Scribe and notch 4" diameter duct for dove tail seam attachment to flat piece (12" square).
3. Bend out every other tab, using stake tool and hammer.
4. Attach flange collar by bending remaining tabs over collar.
5. Install 4 rivets, 90 degrees apart through flange collar and tabs.

NOTE: This project will be used in the installation of air system collectors.

INSTRUCTOR ACTIVITY

Provide sketch, tools and materials (sketch of pitch pan)

LAB/SHOP:

Provide tool, aviation snips, box brake, dividers, hemming tool, rawhide hammer and sheet metal stock, pitch pan drawing, sheet metal stakes, drill motor, drills, screwdriver and sheet metal screws.

Lab Exercise II
Laboratory materials and tools

STUDENT ACTIVITY
Laboratory procedures:

1. From drawing provided, develop notch and bending pattern.
2. Using notching tool and aviation snips, cut blank to pattern size.
3. Bend hems, side flanges, sides and bottom flanges of pitch pan.
4. Assemble using sheet metal screws.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Sequentially list the procedures and fasteners required for roof mounting of solar collectors/racks on:
  A. Built up (felt-tar-gravel) roofs
  B. Asphalt and composition shingle roofs
  C. Wood shingle roofs
  D. Tile roofs.

(2) Describe the procedures used for making and sealing roof penetrations.

(3) Make an acceptable roof penetration and seal with pitch (or other acceptable sealants).

RATIONALE:

The student must have a basic working knowledge of roof types, framing methods and roofing materials so that appropriate solar decisions can be made. One of those decisions, in retrofit installations, may be that of calling for an architectural consultant to determine if the roof structure will support the solar system (collector array). Methods used in mounting the collector array and sealing the roof penetrations are essential to a successful installation.

REFERENCES:

(1) Solar Water and Pool Heating - Installation and Operation, Florida Solar Energy Center, Cape Canaveral, Fl., 1979.

(2) Wagner, Willis H., Modern Carpentry, Goodheart-Willcox, South Holland, Il., 1976.

(3) Capotosts, John, Basic Carpentry, Reston Publishing Co, Reston, Va., 1975.

(4) Griffin, C. W., Manual of Roof Systems, McGraw-Hill Book Co., N.Y., 1970.

UNIT TITLES:

(1) Roof Construction

(2) Roofing Installation Methods

(3) Roof Penetrations and Closures

(4) Solar Collector Mounting

VOCABULARY:

Asphalt Shingles
Roof Tiles
Bundles (shingles)
Underlayment
Flashing
Coverage
Plastic Asphalt Cement
Roll Roofing
Shingle Nails
Pitch Pans
Hips and Ridges
Slate Roofing
Drainage
Sealants
Gutters
Wood Shingles
Squares (shingles)
Sheathing (deck)
Felt
Caps (flashing)
Exposure
Pitch (tar)
Shinglers Hatchet
Shingle Staples
Gravel
Valleys
Metal Roofing
Roof Penetrations
Asbestos-Cement Shingles

Reference 2, Unit 9 Reference 3, Chapter 11	Unit 1. Roof Construction - Describe and Discuss A. Roof types - Flat, shed, gable, hip, gambrel, mansard - pitch angle of these roofs and modifications required for solarization
Reference 3, Chapter 11	B. Roofing Materials 1. Framing - rafters, plates, trusses, gussets, ridges 2. Sheathing (deck) - lathes, metal, concrete, plywood
Reference 3, Chapter 12	3. Underlayment - coated felt, saturated 4. Insulation - purpose, types, R values
Reference 2, Chapter 10	5. Finish covering - asphalt shingles, wood and shake shingles, built-up composition, asbestos-cement shingles, tile shingles, metals, mineral coated roll roofing
Reference 4, Chapter 7	C. Roof flashing - edge flashing, cap flashing, wall flashing, valley flashing, vent flashing
Reference 4, Chapter 3, 6	Unit 2. Roofing Installation Methods - Discuss and Describe A. Deck preparation B. Underlayment application
Reference 2, Unit 10	C. Installation methods and patterns - built-up composition, asphalt shingles, wood shingles, shake shingles, asbestos-cement shingles, tile shingles, metals, mineral coated roll roofing

STUDENT ACTIVITY

Assignment:

Examine a residential roof, possibly your own or one under construction, and write a short report on:

1. Roof type.
2. Pitch angle where collectors could be mounted.
3. Modifications required for solarization.
4. Finish covering utilized.

Reference 2, Unit 10 Reference 4, Chapter 7	Unit 3. Roof Penetrations and Closures A. Types of penetrations required - vents, pipes, drains, wiring, conduit B. Penetration methods - new roof, existing roof
Reference 2, Unit 10 Reference 1, Section 4.4	C. Penetration closure - flashing, pitch pans, plastics, elastomers
Reference 1, Section 5.7	Unit 4. Solar Collector Mounting A. Mounting methods - asphalt shingle roofs, built-up (felt-tar-gravel) roofs, wood shingle roofs, tile roofs, other locally dominant roofs B. Mounting fasteners - asphalt shingle roofs, built-up (felt-tar-gravel) roofs, wood shingle roofs, tile roofs, other locally dominant roofs
Reference 4, Chapter 9	C. Wind loading requirements D. Weatherproofing requirements and methods

STUDENT ACTIVITIES

Assignment:

List and describe the function and relationship of roofing deck, underlayment and finish.

Course Project

Laboratory/Shop Task:

Laboratory Materials and Tools:

Scale model collector rack (from carpentry module), roll felt, asphalt shingles, hand tools, portable drill-motor, drill set, hole saw, short lengths of copper tubing, plastic sealant (mastic), nails, shingle staples, staple gun and circular saw.

Laboratory Procedures:

1. Prepare deck for roll felt.
2. Install roll felt on deck.
3. Install asphalt tab shingles with alternate centered spacing.
4. Trim shingles as required.
5. Make roof penetration for copper tubing.
6. Place copper tubing through roof and secure.
7. Install pitch pan (constructed in Sheet Metal Module) on roof.
8. Install sealant for weatherproofing outside of pitch pan.
9. Install scale model collectors (built by student in Practicum) on the roofing material of the scale model collector rack, using appropriate fasteners for mounting the collectors.
10. Use appropriate sealant for mounting penetrations.

MODULE: SOLDERING

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Select appropriate solder materials, using physical properties of solder and soldered material as criteria for selection.

(2) Make and leak test soft solder and silver solder joints, using vertical, horizontal, and inverted methods, to the satisfaction of the instructor.

RATIONALE:

Soldering is a skill that is very often neglected. It looks so easy, while watching a skilled craftsman making solder joints, that an erroneous assumption leads to problems in the future. This skill (soldering) requires an application of the addage "practice makes perfect", but, there must be a foundation upon which to build with practice. It is essential that the solar technician recognize and be able to implement soldering techniques that do not leak, will not leak, and are structurally sound.

REFERENCES:

(1) Readers' Digest Association, Readers' Digest Complete Do-It-Yourself Manual, Pleasantville, N.Y., 1973.

(2) Cooley, R.H., Complete Metalworking Manual, Arco Publishing Co., N.Y., 1967.

(3) Walker, John R., Modern Metalworking, Goodheart-Willcox, South Holland, Il., 1972.

(4) Young, James F., Materials and Processes, John Wiley and Sons, N.Y., 1954.

UNIT TITLES:

(1) Soldering Processes

(2) Solder Applications

(3) Soldering Equipment

(4) Soldering Techniques

VOCABULARY:

Solders
Reaming
Sil-Phos
Tinning
Lead
Acid Core
Melting Point
Sweat Joints
Presto-Lite Rig
Inner Cone
Cold Flame
Fillets
Fluxes
Pre-Heating
Silver Solder
Antimony
Solder Iron
Wire Solder
Capillary Action
Slip Fittings
Oxyacetylene Rig
Acetylene Feather
Hot Flame

Reference 2, Chapter 15 Pass around to students rolls of soft solder for examination.	Unit 1. Soldering Processes A. Soft solder (50-50, 60-40, 95-5) - physical properties/characteristics, melting and flow temperatures, capillary action, flux material (acid base, resin base, borax base, special bases), joint preparation (flat joints, i.e., sheet metal, cleaning, swedging, fluxing, fittings).
Pass around wire silver solder samples for students percentage decisions.	B. Silver solder (silver content - 565, 1565, 4565) - physical properties/characteristics, melting temperature, flow temperature, flux material, (borax base, special base), joint preparation (cleaning, swedging, fittings, flux application)
Pass around sticks of sil-phos for student examination. Discuss problems of application with 565 sil-phos.	C. Sil-phos (silver content 565, 1565) - physical properties/characteristics, melting point, flow point, joint preparation (cleaning, swedging, fittings).
Reference 2, Chapter 15 Reference 3, Chapter 7	Unit 2. Solder Applications A. Structural requirements - high pressure, medium pressure, low pressure, yield strength B. Selection criteria - materials to be joined, structural requirements, limitations (working space flexibility, operational requirements).
Demonstrate Soldering Equipment. Reference 1, pp. 230-231 Reference 2, Chapter 15	Unit 3. Soldering Equipment A. Oxyacetylene rig - pressure setting (acetylene, oxygen), tip selection, flame patterns B. Presto-lite rig - pressure regulation, tip selection, flame patterns C. Soldering irons - electric, flame heated D. Soldering pots

Demonstrate Soldering Techniques

Unit 4. Soldering Techniques

- A. Tubing joints - horizontal, vertical, inverted
- B. Lap joints
- C. Post-solder clean-up
- D. Leak testing (vapor pressure, liquid pressure, vacuum test).

STUDENT ACTIVITY

Assignment:

List melting temperatures of

1. Soft Solders.
2. Silver solders.
3. Sil-phos.

Lab Exercise I

Laboratory Tasks:

Laboratory Materials and Tools:

Presto-lite torch rig, tips, 95-5 wire solder, silver solder, sil-phos, flux, striker, tank wrench, 3 swedge joints of copper tubing.

Lab Procedure:

1. Soft solder a copper swedge joint.
2. Silver solder a copper swedged joint.
3. Sil-phos a copper swedged joint.
4. Inspect for possible leaks.

Lab Exercise II

Laboratory Tasks:

Laboratory Materials and Tools:

Piping sketch using swedge joints, fittings, and pinch joints; copper tubing of at least two sizes, soft solder, silver solder, sil-phos, oxyacetylene rig, tips, striker, fluxes.

Laboratory Procedures:

1. Complete piping task per sketch provided using soft solder, silver solder and sil-phos.
2. Leak test.

MODULE: PIPING PRACTICES

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify common plumbing tools and demonstrate appropriate applications.

(2) Identify (by type and size) male and female pipe and fittings.

(3) Identify (by type and size) copper tubing, copper fittings, and brass fittings.

(4) Construct a piping project, using three or more piping techniques, that does not leak.

RATIONALE:

Skills in piping practices are absolutely essential to successful solar technicians. They must be able to recognize good piping practices and demonstrate ability in making many kinds of piping joints for various applications including the collector and storage systems.

REFERENCES:

(1) Readers' Digest Association, Readers' Digest Complete Do-It-Yourself Manual, Pleasantville, N.Y., 1973.

(2) Air Conditioning and Refrigeration Institute, Refrigeration and Air Conditioning, Prentice-Hall Inc., 1979.

(3) Bolin, Everet W., Piping and Fittings, Dallas County Community College District, Dallas, Texas, 1978.

UNIT TITLES:

(1) Iron Pipe

(2) Copper Tubing

(3) Plastic Piping

(4) Pipe and Tubing Supports

VOCABULARY:

Iron Pipe
P.V.C. Tubing
De-Burr
Flare
A.B.S. Tubing
Plastic Pipe Cements
Hangers
Tees
Adapters
Bushings
Caps
Unions

Copper Tubing
Brass Fittings
Swedge
C.P.V.C. Tubing
Bends
Plastic Pipe Solvents
Elbows
Crosses
Reducers
Couplings
Plugs
Return Bends

Reference 1, Section 7 Pass around fittings for student examination.	Unit 1. Iron Pipe - Discuss and Demonstrate A. Sizes and types - appropriate applications, inappropriate applications B. Cutting, de-burring and threading C. Welded construction - applications D. Fittings - elbows, tees, reducers, bushings, couplings, unions, caps, plugs, adapters, crosses
Demonstrate proper application of sealants. Discuss appropriate application for each type.	E. Joint sealants - pipe dope, lock-tite, teflon tape
Reference 1, Section 7 Reference 2, Chapter 5 Reference 3, Unit 10, 15	Unit 2. Copper Tubing - Discuss and Demonstrate A. Sizes and types - appropriate applications, inappropriate applications B. Cutting and de-burring - tubing cutter, saw fixture, de-burring tools
Reference 3, Unit 5	C. Flaring - flaring methods, flaring tools, flare sizes, single flare, double flare
Reference 3, Unit 15	D. Swedging - swedging methods swedging tools, swedge sizes E. Hand benders - spring benders, custom bending F. Mechanical bending tools - precision bends, bend allowance, pre-cut lengths
INSTRUCTOR ACTIVITY	Demonstration: Demonstrate the proper use of tools for cutting, de-burring, flaring, swedging, and bending copper tubing.
Reference 1, Section 7 Reference 3, Unit 5	G. Copper fittings - types and sizes, elbows, tees, reducers, couplings, caps, adapters, bushings, unions, crosses
Pass around copper and brass fittings for student examination. Describe applications and how to make identification of fittings.	H. Brass fittings - types and sizes, elbows, tees, unions and half unions, reducers, caps, plugs, adapters, bushings, crosses, flare nuts, flare caps

Reference 1, Section 7

Unit 3. Plastic Piping - P.V.C., C.P.V.C., A.B.S. - Discuss and Demonstrate

- A. Tubing - types and sizes
- B. Cutting and de-burring
- C. Solvents and cements
- D. Fittings - elbows, tees, adapters (N.P.T. x slip), nipples, reducers, crosses, plugs, caps

INSTRUCTOR ACTIVITY

Demonstration:

Demonstrate cutting methods, de-burring, use of solvents and cements, and installation of fittings used in plastic piping.

Unit 4. Pipe and Tubing Supports - Discuss and Describe

- A. Hangers - types and methods
- B. Spacing - vertical and horizontal
- C. Drain pitch

STUDENT ACTIVITY

Laboratory:

From a group of fittings, consisting of iron pipe, copper, brass, and P.V.C. fittings, the student will identify them by classification, type and size.

Lab Exercise I

Laboratory Task:

Laboratory Materials and Tools:

A plumbing sketch that includes flare fittings, swedged fittings of different sizes and two or more bends. Copper tubing, copper fittings, flaring tools, cutting tool, swedging tools, end wrenches and air pressure source.

Laboratory Procedures:

The student will construct the plumbing project to meet specifications and pressure test for leaks.

NOTE TO INSTRUCTOR: These skills will be utilized in plumbing the collectors to the scale model collector rack toward the end of this course.

Lab Exercise II

Laboratory Task:

Laboratory Materials and Tools:

Provide a P.V.C. piping sketch requiring the use of a P.V.C. coupling, elbow, and tee. P.V.C. tubing, hacksaw, de-burring tool, P.V.C. fittings, solvent and cement.

Laboratory Procedures:

Join the fittings to the tubing, using solvent and cement. After curing, saw fittings at the joint and peel apart to check for seal.

Course Project
INSTRUCTOR ACTIVITY

Provide a piping sketch of the collector loop for the scale model system, copper tubing, fittings, solder, soldering equipment, and indicated heat exchanger.

STUDENT ACTIVITY

Assignment:

1. Examine the piping sketch and select the necessary fittings and components.
2. Cut the required lengths of copper tubing.
3. Pipe the system, per sketch, making certain to protect any components that could be damaged by heat. Protection can be provided by wet cloth or disassembly of component.
4. Leak test the system and make any necessary repairs.

MODULE: GLAZING

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Select the correct glazing material for the application.

(2) Utilize appropriate glazing tools.

(3) Install, using correct techniques, a piece of glazing.

RATIONALE:

The glazing is a very important component of the collector system. A working knowledge of the optical characteristics and installation procedures for glazing replacement is essential to the solar technician. Knowledge of available sizes is a necessity in designing a system.

REFERENCES:

(1) Readers' Digest Complete Do-It-Yourself Manual, Readers' Digest Association, Pleasantville, N. Y., 1973.

(2) Holloway, Dennis G., Physical Properties of Glass, Wykeham Science Series, Crane Russok Publishers, N. Y., 1973.

(3) Doors and Windows, Time-Life Books Inc., Alexandria, Va., 1978.

(4) Maloney, Francis J., Glass in the Modern World, Doubleday and Co., Garden City, N. Y., 1968.

(5) Cadillac Plastics Buyers Guide, Cadillac Plastics Inc., Dallas, Tx., 1976.

(6) Ulray, Harry F., Carpenters and Builders Library, Vol. 4, 3rd ed., Audel and Co., Indianapolis, In., 1973.

UNIT TITLES:

(1) Manufacturing Process

(2) Glazing - Physical Properties

(3) Optical Characteristics

(4) Selection Criterion

(5) Available Sizes

(6) Glazing Tools and Materials

(7) Installation Procedures

VOCABULARY:

Sheet Glass
Plate Glass
Absorptive Glass
Tempered
Wired Glass
Single Strength
High Strength
Glazing Compound
Glass Grinders
Gaskets
Acrylics
Tedlar
Fiberglass
Mil (thickness)
Float Glass
Tinted Glass
Block Glass
Laminated
Thermal Glass
Double Strength
Impact-Resistance
Glass Cutters
Templates
Glazing Channels
Polycarbonates
Teflon
Thermoformed

MODULE: GLAZING

Reference 4 & 5 (no chapters)	Unit 1. Manufacturing Process (Brief)-Discuss A. Glass B. Plastics
Reference 2, Chapter 2 Reference 6, Chapter 12	Unit 2. Glazing - Discuss Physical Properties A. Hard Glazing (glass) - sheet glass, float glass, plate glass, tempered glass, wired glass, laminated glass, tinted glass, thermal glass, absorptive glass, block glass B. Soft Glazing (Plastics) - acrylics, polycarbonates, tedlar, teflon, fiberglass
Reference 6, Chapter 12 Reference 2, Chapter 3	Unit 3. Optical Characteristics (Brief) Discuss and Demonstrate A. Transmissivity - hard glazing, soft glazing B. Reflectivity - hard glazing, soft glazing C. Absorptivity - hard glazing, soft glazing
Reference 6, Chapter 12	Unit 4. Selection Criteria - Discuss A. Hard Glazing - application (collector glazing, windows and doors, structural component, handling), strength criteria (collector glazing, windows and doors, structural component, handling), thermal criteria, optical criteria
Reference 5	B. Soft Glazing - application (collector glazing, windows and doors, structural component, handling), strength criteria (collector glazing, windows and doors, structural component, handling), thermal criteria, optical criteria
	Unit 5. Available Sizes - Discuss and Describe A. Hard Glazing - length, width, thickness B. Soft Glazing - length, width, thickness
Reference 1, Section 13 Reference 3, pp. 50-56	Unit 6. Glazing Tools and Materials (Field Installation) A. Tools (Hard Glazing) - cutters, pliers, drills, oil stones, grinders, flexible tape, straight edge

Reference 1, Section 13

B. Tools (Soft Glazing) - cutters, knives, saws, pliers, drills, grinders, flexible tape, straight edge, dividers

Reference 1, Section 13
Reference 3, pp. 50-56

C. Gaskets, sealers, and retainers - putty (glazing compound), rubber gaskets, plastic gaskets, spring clips, cap strips

INSTRUCTOR ACTIVITY

Demonstrate the installation process for the glazing on a flat plate collector.

Unit 7. Installation Procedures - Demonstrate

A. Safety - gloves, goggles, handling, storage, accessibility, transportation
B. Remove the broken glazing
C. Remove the glazing gaskets, sealers, or retainers
D. Clean the channel
E. Insert replacement glazing
F. Secure replacement glazing
G. Clean-up procedures

STUDENT ACTIVITY

ASSIGNMENT:

Given a glazing application, select the most appropriate glazing material, tools required and sequentially list installation procedure.

Lab Exercise I

Laboratory Tasks:

Laboratory materials and tools:

Demonstration flat plate solar collector, hand tools, gloves, goggles, sealant, or gasket. (Two persons required for this task).

Lab Procedures:

1. Remove glazing retainer.
2. Remove gasket or sealant compound.
3. Remove glazing and store in safe place.
4. Clean channel, gasket and glazing.
5. Replace, seal, and secure glazing.

Lab Exercise II

Laboratory materials and tools: Multipane window frame, glass, sealant, retainers, glass cutter, gloves, and goggles.

Lab Procedures:

1. Measure size required and cut glass to fit opening.
2. Remove glass slivers from edges.
3. Clean channel.
4. Install glazing.
5. Secure and seal glazing.

MODULE: COATINGS, COMPATIBILITY AND INSULATION

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Select the appropriate material coating using application as criteria for selection.

(2) Describe problems encountered when incompatible materials are applied.

(3) Select the most appropriate insulation using application and thermal properties as criterion for selection.

(4) Insulate piping and storage vessels, using appropriate material.

RATIONALE:

Many solar systems fail because material compatibility was not considered. The life expectancy and aesthetic appearance of a solar system can be greatly enhanced by proper coatings, and system performance can be improved significantly with appropriate insulation. These considerations must become second nature to the solar technician.

REFERENCES:

(1) Readers' Digest Association, Readers' Digest Do-It-Yourself Manual, Pleasantville, N.Y., 1977.

(2) Ulrey, Harry F., Carpenters and Builders Library, Vol. 4, 3rd Ed., Audel and Co., Indianapolis, In., 1973.

(3) Budzik, Richard S., Sheet Metal Technology, Howard W. Sams Co., Indianapolis, In., 1971.

(4) Cooley, R.H., Complete Metalworking Manual, Arco Publishing Co., N.Y., 1975.

(5) Handbook of Fundamentals, ASHRAE, N.Y., 1976.

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(7) Kreith, Frank, Principles of Heat Transfer, Intext Press Inc., N.Y., 1973.

UNIT TITLES:

(1) Coatings

(2) Material Compatibility

(3) Insulation

VOCABULARY:

- Paint
- Lacquer
- Epoxy
- Binder
- Solvent
- Primer
- Semi-Gloss
- Emulsion
- Urethane
- Brush
- Spray Gun
- Plating
- Galvanic Action
- Bonding Agent
- U-Valve
- Varnish
- Polymers
- Pigment
- Thinner
- Catalyst
- Gloss
- Flat
- Silicones
- Stain
- Roller
- Anodize
- Electrolysis
- Bimetal
- R-Valve
- Resistance

Reference 1, Section 10 Reference 2, Chapter 12	Unit 1. Coatings - Discuss and Demonstrate
	A. Purpose - esthetic appearance, environmental protection, increase material life span, sanitation
Reference 1, pg. 334 Reference 2, chapter 12	B. Wood Coatings - physical characteristics of paint, lacquer, varnish, shellac, primer, epoxy, latex, oils, urethanes, vinyls
Reference 3, Chapter 17 Reference 4, Chapter 14 Reference 2, Chap. 12	C. Metal Coating - physical characteristics of plating, anodizing, electrolysis, galvanic action, films (plastic), paint, lacquer, primer, epoxy
	D. Material preparation - woods, metals
	E. Applicators - brushes, rollers, electroplating, dip vats
	F. Curing - wood coating, metal coatings
Reference 3, Chapter 3	Unit 2. Material Compatibility - Discuss and Demonstrate
Give attention to thermal coefficients and galvanic reaction.	A. Chemical reaction - electrolysis, corrosion, rust
	B. Physical reaction - thermal expansion differences, thermal conductivity differences
Reference 1, Section 9	Unit 3. Insulation - Discuss and Describe
	A. Physical properties - fiber glass, rock wool, closed cell plastics
Reference 7, Chapter 6 & 7 Reference 6, Chapter 4	B. Thermal properties - resistance to heat flow, K-factor, C-factor, R-value, U-value
Reference 5, Section 3	C. Limitations - ultra-violet exposure, fiber glass (bonding agent, texture, settling), rock wool (texture, settling)
Reference 6, Chapter 4	D. Vapor barriers - plastic, metallic
Reference 5, Section 3	E. Installation methods - fiber glass, rock wool, closed cell synthetics

STUDENT ACTIVITY	Assignment:
	Given an application, select the appropriate material coating for durability, environmental protection, and aesthetic value.
Lab Exercise I	Laboratory Tasks:
Laboratory Materials and Tools:	A product that has encountered problems from material incompatibility.
Laboratory Procedure:	Analyze and describe the problem, causes, and preventative measures required to eliminate the problem.
Lab Exercise II	Laboratory Tasks:
Laboratory Materials and Tools:	An application that requires insulating material for thermal retardation.
Laboratory Procedure:	Using the application, thermal requirements, and physical/thermal properties of insulating materials, select the most appropriate insulation for the job.
Lab Exercise III	Laboratory Tasks:
Laboratory Materials and Tools:	The scale model collector rack (mounted collectors and piping complete), insulation materials for piping, collector backing, and storage vessels.
Laboratory Procedures:	1. Insulate the piping as required, using the appropriate material. 2. Insulate the collector back and edges if required. 3. Insulate the storage vessel, using the appropriate material.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Select the appropriate service panel, based upon source voltage and load requirements.

(2) Mount a disconnect box using appropriate techniques and fasteners.

(3) Using wire gauge, insulation, and number of conductors as criteria, select the appropriate wire for a given application.

(4) Cut and bend conduit per specifications.

(5) Attach rigid or flexible conduit to electrical boxes, using the appropriate connectors.

(6) Calculate the circuit load and select appropriate circuit protection devices.

RATIONALE:

This module is intended to make the student familiar with common wiring practices and load requirements that may be utilized in the installation of a solar system. Service panels, circuit protection, and installation techniques are emphasized while applications are left to the discretion of the instructor so that individual needs may be met. Instructional aids and references are noted, offering a variety of teaching strategies.

Electrical current, Ohm's law, series, parallel, and combination circuits are taught in the Energy Science Courses. Magnetism and motors are also presented in the courses. It is not intended that this module be used to train electricians.

REFERENCES:

(1) Readers' Digest Association, Readers' Digest Complete Do-It-Yourself Manual, Pleasantville, N.Y., 1973.

(2) Richter, H.P., Practical Electrical Wiring, McGraw-Hill Book Co., N.Y., 1976.

(3) Herrick, Clyde N., Electrical Wiring, Principles and Practices, Prentice-Hall, Englewood Cliffs, N.J., 1975.

MODULE: ELECTRICITY

UNIT TITLES:

(1) Service Entrance Panel
(2) Branch Circuits
(3) Electrical Boxes and Conduit
(4) Circuit Protection
(5) Electrical, Electro-Mechanical Devices

VOCABULARY:

Service Panel
Fuse
Fuse Box
Wire Nut
Splices
Load Circuit
Alternating Current
Switches
Alarms
Transformer
Relay
Motor Starter
Electric Motor
Wire Gauge
Diagonal Cutter
Extension Cords
Conduit Connectors

Circuit Breaker
Breaker Box
Disconnect Box
Electrical Tape
Terminal Fittings
Control Circuit
Direct Current
Receptacles
Conduit
Branch Circuit
Conductor
Electric Motor
Wiring Code
Wire Stripper
Overloads
Conduit Bender

Reference 1 thru 4 Reference 3, Chapter 2	Unit 1. Service Entrance Panel - Discuss and Describe
	A. Describe sources of electricity - A.C. generation, D.C. generation, chemical storage batteries
	B. Discuss delivery system
	1. Transmission/distribution lines, high voltage lines
Show line drawing overhead transparency, or diagram on chalkboard. (Reference 3, pg. 43)	2. Transformers - types, transformer taps, voltage step-up, voltage step-down
Show line drawing overhead transparency, or chalkboard diagram of transformer line taps required to obtain these voltages.	3. Common residential voltage - 117V single phase, 208V single phase, 230V single phase
	4. Selected industrial voltages - 208V single phase, 208V three phase, 230V single phase, 230V three phase, 460V three phase
Reference 2, pg. 198	C. Service entrance criterion - current requirements, lighting load, appliance load, heating/cooling load, wall receptacles load
	D. Explain metering devices - watt/hour meter, power factors, efficiency factors, peak demand factors
	E. Service panel and disconnect installation - methods of mounting the service panels, purpose and need for the disconnect box, methods of mounting disconnect boxes
INSTRUCTOR ACTIVITY	Lab/Demonstration: Provide a demonstration board (plywood with support for upright position); load requirements for a residential building; at least three disconnect boxes of different voltage and current ratings and a variety of fasteners.

STUDENT ACTIVITY

Laboratory:

1. The students should select the appropriate disconnect box for the given application.
2. The students should mount the disconnect box to the demonstration board, using the appropriate fasteners.

Reference 1,2, and 3
Reference 1, pg. 254
Show line drawing of branch circuits similar to Reference 1 pg. 254. (overhead transparency or handout)

Unit 2. Branch Circuits - Describe Functions and Applications

A. Purpose and function - circuits balanced, typical load combinations

National and local code book.

Wire gauge tool.

Variety of wire connectors such as wire nuts, splices and screw clamps.
Reference 1, pg. 268

B. Branch circuit wiring - conductor materials, current capacity, solid wire, stranded wire, wire gauge tool, insulation/voltage, wire connectors

C. Applications - load circuits, control circuits, control circuits and ground circuits

Clamps, staples

D. Fastening methods - clamps, staples, holes

Reference 1, pg. 261

E. Characteristics of wire - number of conductors, insulation characteristics, shielding, underground wiring

INSTRUCTOR ACTIVITY

Laboratory:

Provide variety of wire sizes, insulation, and number of conductors.

STUDENT ACTIVITY

Laboratory:

Given the application and load requirements, the student should select the appropriate wire type, using gauge, insulation and number of conductors as criterion for the application.

Reference 1 thru 4

Unit 3. Electrical Boxes and Conduits - Application and Use

Variety of electrical boxes
Reference 1, pg. 260

A. Electrical boxes - wall boxes, waterproof boxes, ceiling boxes

B. Mounting procedures - wall boxes, waterproof boxes, ceiling boxes

Small pieces of thin wall and flexible conduit.

A variety of couplings adapters elbows, waterproof fittings of various sizes.

Tubing cutter, hacksaw and conduit bender.

C. Conduit - thin wall conduit, flexible conduit
D. Demonstration conduit fittings - couplings, adapters, elbows, waterproof fittings
E. Demonstration cutting and bending conduit - cutting flexible conduit, cutting thin wall conduit, bending thin wall conduit

INSTRUCTOR ACTIVITY

Lab/Demonstration:

Provide thin wall conduit, flexible conduit, hacksaw, conduit bender, tubing cutter, conduit connectors, and a wall box.

STUDENT ACTIVITY

Laboratory:

1. Make a 90 degree bend in a piece of 1/2" conduit.
2. Cut off the conduit 4" beyond the tangent point of the bend.
3. Attach the conduit to the wall box, using the appropriate connectors.
4. Cut off, using the hacksaw, a piece of flexible conduit 6" long.
5. Attach the conduit to the wall box, using the appropriate connectors.

Reference 1 thru 4

Pass around to the students fuse boxes, a variety of fuses and circuit breakers.

Unit 4. Circuit Protection - Describe Purpose and Operation
A. Common types of circuit protection - fuse boxes, plug fuses, cartridge fuses, renewable fuses, circuit breakers
B. Discuss circuit current rating, protection rating

Reference 2, pg. 80
Reference 3, pg. 71
Reference 1, pg. 252

NOTE: Caution against oversizing or by-passing the protective device.

Reference 1, pg. 254

C. Sizing the protective device - branch circuit loads, total current load, appropriate circuit protection

INSTRUCTOR ACTIVITY

Lab/Demonstration:

Select an electrical panel (possibly one in your laboratory) with circuit breakers. Select circuit breakers where the load is known.

STUDENT ACTIVITY

(Could be Instructor Demonstration)

Laboratory:

1. Total the loads on a circuit.
2. Compare the calculated total load with the rating of the circuit breakers.
3. Remove the panel skirt, observe and note the wiring techniques and circuit breaker mounting method.

Reference 1,2, and 3

Unit 5. Electrical, Electro-Mechanical Devices - Discuss and Demonstrate

Reference 1, pp. 262-268
Reference 3, pg. 121

A. Common electrical devices - switches, receptacles, lights - including pilot lights, buzzers, bells, thermostats

Reference 2, pg. 252
Reference 3, pg. 215

B. Electrical-mechanical devices - relays and contactors, motor starters and motors, solenoids

MODULE PROJECT:

Note to the Instructor:

The following project would be quite useful in demonstration of electrical service, loads, circuits, and controls. If time permits, it would be a very good student/class project. It will be useful in demonstration of very basic control circuits in the Collectors and Energy Storage course.

Materials and Tools Required:

3/8" plywood (2′ x 4′) with supporting structure for upright position, disconnect box, switchbox, two lamp receptacles, 10 ft. of flexible conduit, single plug-in fuse box, live voltage thermostat (SPDT) with sub-base, hacksaw, conduit connectors, and 10 ft. of 12 gauge solid wire.

Lab Procedure:

NOTE TO INSTRUCTOR: (You may need to furnish the students with a schematic or pictorial diagram)

1. Draw a simple layout of the components, locating them on the board, leaving sufficient room between components that require conduit.
2. Mount the disconnect, fuse box, switch box, and lamp receptacles to the board.
3. Cut the conduit to appropriate length, using the correct connectors.
4. Wire the board so that the lights are controlled by the thermostat sensor and switch position.

MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

Representative Labs

LAB: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

Lab 1: Safety

Safety is an attitude and must therefore become a part of the subconscious if one is to be a "safe worker". Learning to recognize unsafe and potentially hazardous conditions is a part of safety consciousness.

1. Make an inspection of your lab facility (and any other areas your instructor might designate). List and categorize conditions as follows:
   a. Unsafe, i.e., oil on floor, poor ventilation, etc.
   b. Potential Hazard, i.e., welding tanks insecured, loose walk boards, etc.
2. Make recommendations as to what would be required to make the area safe.

Lab 2: Units of Measurement

Fabrication processes require the use of measurements and measuring devices. Layout and measuring skills are necessary if the assembled product is to be acceptable, particularly if sub-assemblies and/or components are required.

1. Measure and record the dimensions of random pieces of material, such as wood, tubing, sheet metal, etc.

   A. ____________________

   B. ____________________

   C. ____________________

   D. ____________________

   E. ____________________

2. Layout a piece of 2" x 4" lumber 12" long to the short side of a 45° angle.

3. Layout a hole pattern for 4 equally spaced 3/8" dia. holes (material furnished by lab assistant).

4. Using an outside micrometer, record the diameter or thickness of material such as tubing, bolts, nails, etc. (furnished by lab assistant).

   A. ____________________ D. ____________________

   B. ____________________ E. ____________________

   C. ____________________ F. ____________________

5. **Using vernier** calipers, measure and record the root diameter of the threaded part of a lag bolt and the inside diameter of a piece of tubing.

A. Lab bolt ____________________

B. Tubing ____________________

6. Calculate the area of the 2" x 4" layout in No. 2.

Area = ____________________

7. Using a telescoping gauge, O. D. micrometer, and vernier caliper, calculate the volume of 3 pieces of tubing furnished by lab assistant.

A. ____________________

B. ____________________

C. ____________________

Lab 3: Hand Tools/Power Tools

On site installation of solar systems requires basic skills in some power tools and hand tools. Safe and proper use of these tools is critical. This lab will provide training in the use of common power tools. Hand tool use will be incorporated in labs following. Close supervision is necessary for these activities.

1. Using a circular saw and 1" x 4" lumber (provided by lab attendant) layout and cut 4 pieces 8" long.
2. Using a circular saw and hand saw, layout and cut a piece of hard board 8 3/4" square.
3. Layout and cut, using a saber saw, a 2" square cutout in the center of the 8 3/4" square hard board.
4. Layout 3 equally spaced holes, 2 inches apart. Using a portable drill motor and a 3/4" hole saw, drill 3 3/4" diameter holes in one piece of the 1" x 4" stock cut in step 1.

Lab 4: Fasteners

Assembly of components in building and installing solar systems requires the use of a variety of fasteners.

1. Assemble 4 pieces of 1" x 4" lumber, using the correct nails, so that it is a square assembly 4" high. Be careful that the wood does not split.

2. Using pan head screws, fasten a piece of fiber board to the top side of the above assembly, using 4 screws.

3. Cut 2 pieces of 14 ga. stranded wire, strip as required and join using wire nuts.

4. Fasten a piece of fiber board to a piece of sheet rock using 1 molly bolt and 1 toggle bold (material furnished by lab assistant).

Lab 5: Welding

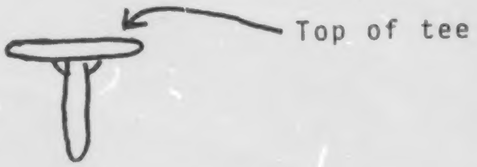
Oxy-acetylene welding and torch cutting is a process frequently used in assembling and installing solar systems. Safety precautions in assembling and using the oxy-acetylene rig are absolutely essential.

1. List the safety rules that are applicable to set-up and use of the oxy-acetylene rig.
2. Set-up the oxy-acetylene rig for welding/brazing. Adjust pressure regulators and select torch tip for 1/8" thick steel. Be sure to leak check all fittings.
3. Light torch and adjust flame for brazing.
4. Extinguish torch flame by using appropriate shut-down procedures.
5. Install torch-cutting head and adjust pressure regulators for cutting 1/4" steel.
6. Light and adjust cutting torch flame.
7. Using the cutting torch, cut 4 pieces 1/4" x 2" x 8" hot rolled steel.
8. Have lab assistant inspect your cuts.
9. Disassemble oxy-acetylene rig and return to proper storage.

Lab 6: Welding

Arc welding provides a rapid method of making very strong weld joints. It is the method commonly employed in assembling steel collector racks and is also useful in commercial solar installations where large mounting and tracking systems are required.

1. Set up the arc welder according to directions presented in the lecture.
2. Select appropriate electrodes and set up 2 pieces of 1/4" x 2" x 8" (torch-cut from previous lab) for a butt weld. Practice running beads on one side until you can run a bead at least 2 inches long with uniform width and penetration.
3. Butt weld the two pieces together using a weave pattern. (crescent, circular, figure 8).
4. Chip and brush weld joint. Have the weld inspected by lab assistant.
5. Using the two remaining pieces from the previous lab, set-up and make a tee section by welding them together.



6. Chip and clean weld joint. Have weld inspected by lab attendant.

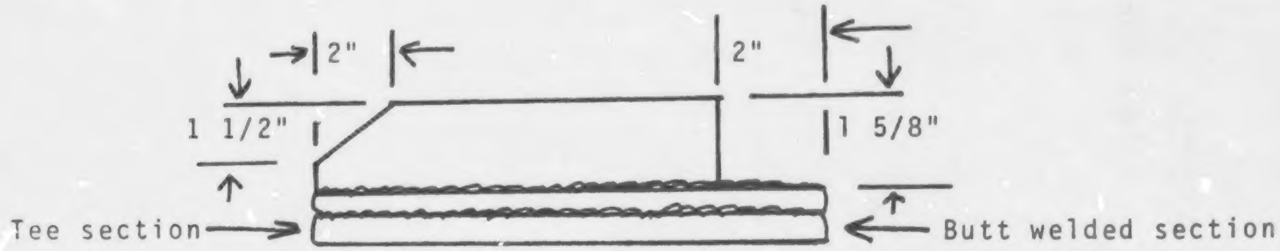
7. Set up and make a lap joint by welding top of tee section to the flat side of one of the butt welded pieces. Clean joint and have lab assistant inspect welds.

Notches and angle relief cuts are sometimes necessary to facilitate assembly or movement. The oxy-acetylene cutting torch is very useful in making these kinds of cuts.

1. Lay out cuts using chalk or soapstone per sketch below.

2. Have lab attendant inspect layout.

3. Torch cut angles and notches per sketch.



Lab 8: Carpentry/Roofing

The following lab will provide practice in developing basic installation of solar systems, particularly collector mounting procedures.

1. Using model roof section and attached sketch:
   a. Prepare sleepers by cutting to length and notching for drainage.
   b. Apply sealant to underside of sleepers and attach to roof at designated locations (see sketch). Use hardware as required.

2. Make roof penetrations for piping as shown per sketch.

3. Have lab attendant inspect your work.

4. Set these assemblies aside. They will be used in labs following this one.

Lab 9: Sheet Metal/Flashing/Pitch Pans

The pitch pan is used to seal large roof penetrations or to secure devices to a roof structure without penetrating the roof. Many times it is more practical to construct a pitch pan on the job site.

Another sheet metal device that is often used in solar installations, particularly air systems, is the dove tail starting collar. Skills must be developed in the construction of these two sheet metal fittings.

1. Using a piece of round duct, provided by your instructor, cut it to the length prescribed by the lab attendant.

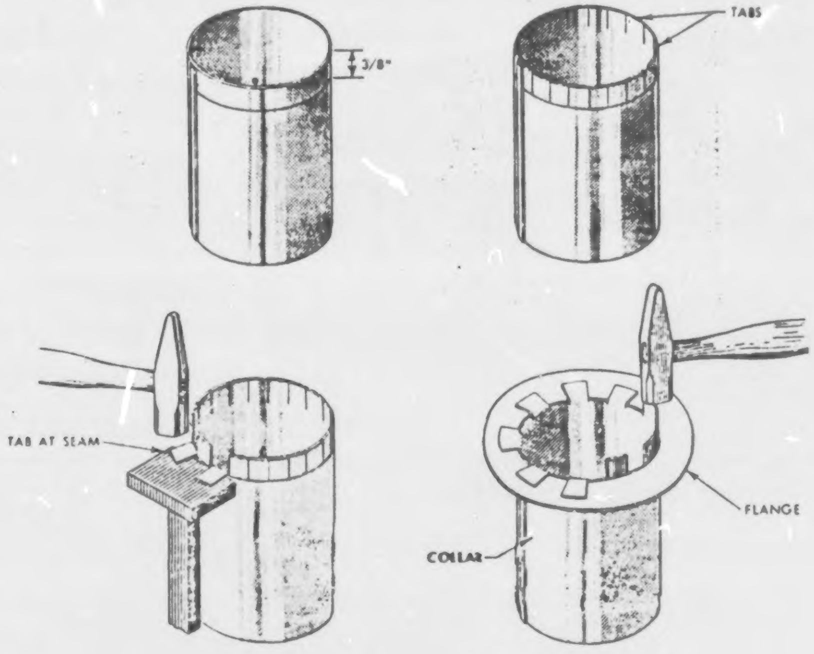
2. Lay out the tabs as shown in the sketch below.

3. Using a pair of tin snips, make tab cuts.

4. Using a pair of dividers (or trammel points) lay out two circles on a piece of sheet metal flat stock provided by lab attendant.

5. Using the appropriate aviation snips, cut out a flange that fits the outside diameter of the duct and provides a 2" wide flange.

6. Assemble the starting collar as shown in the sketch.



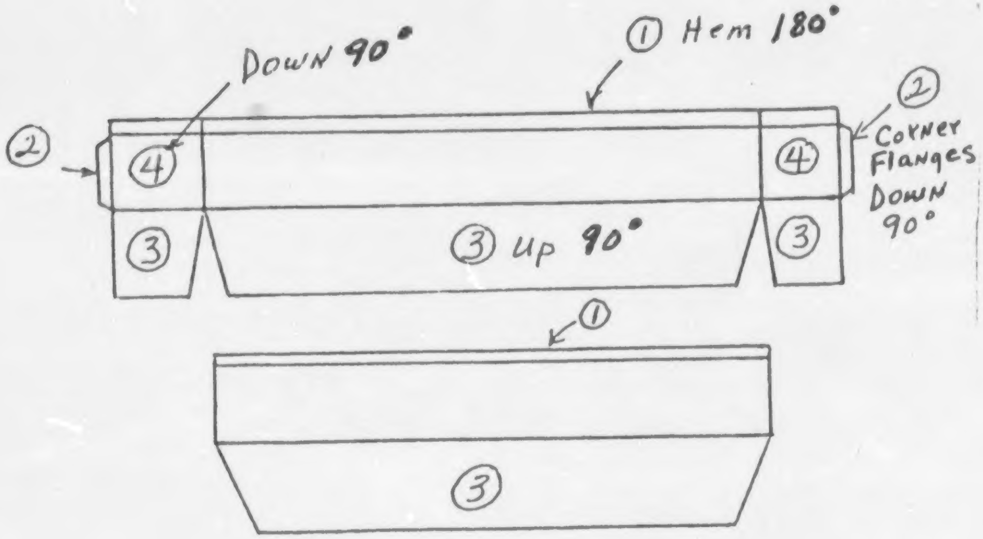
BENDING EVERY OTHER TAB OUT

BENDING REMAINING TABS OVER FLANGE

Making a dovetail seam.

7. Using material provided by the lab attendant, lay out a pitch pan that will have finished formed dimensions of 3" wide, 6" long, 2" high with 2" flanges and 1/2" hem. (See sketch below).

8. Cut and form pitch pan per directions below. NOTE: This pitch pan is of 2 piece construction with the corner flanges attached to the other side with solder, rivet, or screws.



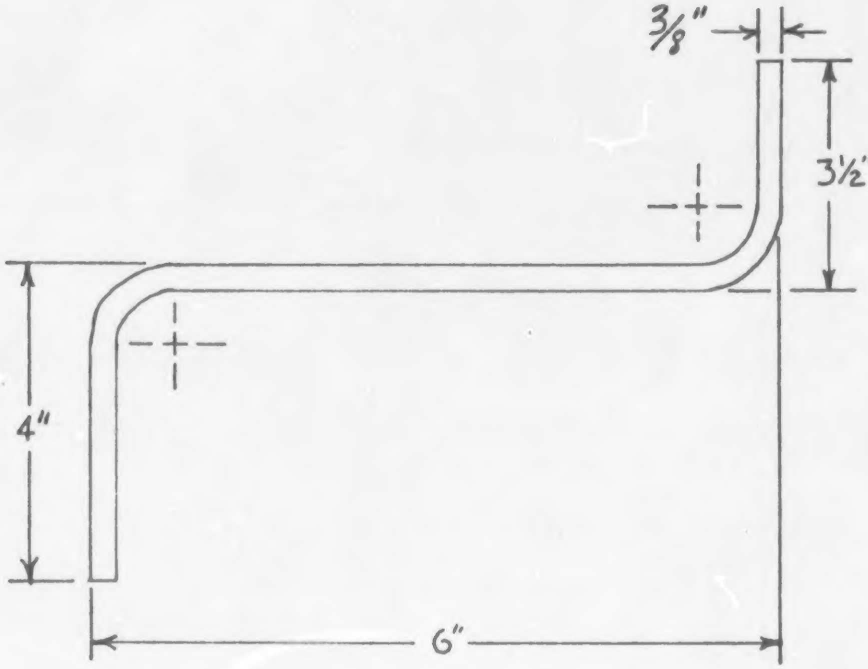
a. Select the appropriate material for the manufacture of this pitch pan and lay it out according to the dimensions provided by the instructor in the pattern as shown above.
b. Fold the hem upward and then all the way down to 180° bend. The hem is marked by the number 1.
c. Fold the corner flanges number 2, down 90°.
d. Fold the roof flashing flanges marked number 3 up 90°.
e. Fold the end pieces marked number 4 down 90°.

This should complete the forming of this pitch pan and the attachment of the opposite side can be accomplished through the use of rivets, solder or glue if cardboard was chosen as the material for construction.

Lab 10: Piping Practices

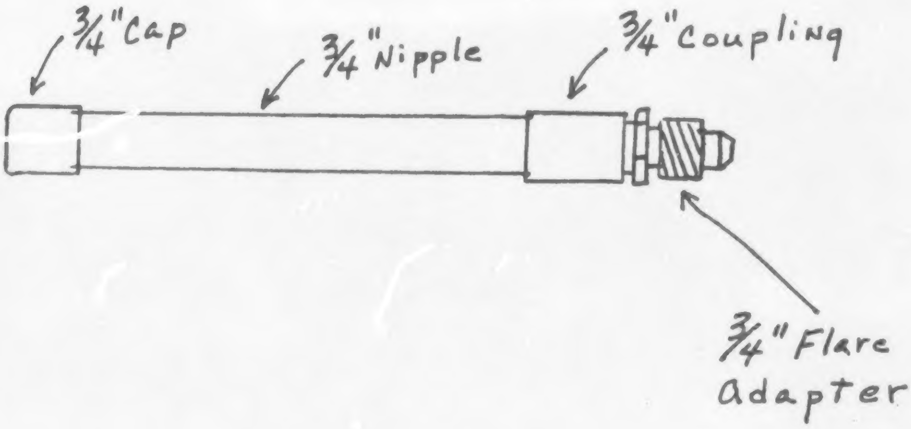
Skills in selecting the correct pipe and fittings are valuable to the solar technician; however, it is also essential that proper techniques are used when preparing and assembling piping tasks. Pipe assemblies can be made through solder swaged joints, flare fittings, pipes threads, couplings, tees, elbows, etc. This lab will assist in developing these required skills.

1. Obtain pieces of 1/4", 3/8" and 1/2" copper tubing 18" long.
2. Cut the tubing into 3" lengths (18 pieces).
3. Deburr the tubing.
4. Swage the tubing so that you have three swaged joints for each size.
5. Have the lab attendant evaluate your work.
6. Obtain a set of flaring tools, a 1/4", 3/8" and 1/2" flare nut and a deburring tool.
7. Using 1 swaged piece of each size tubing, on the end that is not swaged, slip the flare nut over the tubing and make a flared fitting.
8. Have your work evaluated.
9. Obtain two 18" lengths of 3/8" dia. tubing, a spring bender, and a 3/8" mechanical bender. Using the spring bender, make a 180° bend in the 3/8" tubing that measures 3" ± 1/4" in diameter at the tangent points. Remove the spring bender.
10. Have your work evaluated.
11. Using the mechanical bender and the other 18" length of 3/8" tubing, bend the tubing to the dimensions shown in the sketch on next page.



12. Have the lab attendant evaluate your work.

13. Using a 6" long, 3/4" N.P.T. nipple, a cap, a coupling and a N.P.T. to flare adapter, assemble, using teflon tape on the pipe threads, per sketch below.


3/4" Cap
3/4" Nipple
3/4" Coupling
3/4" Flare Adapter

14. Pressure test the assembly using air or refrigerant.

15. Have your work evaluated.

Lab 11: Soldering

Skills in soft soldering, silver soldering and silver brazing are absolutely essential to successful assembly and installation of solar systems. Liquid System leaks, from poor solder joints are a major cause of warranty calls. Leaks, resulting in loss of fluids, also can cause damage to other components such as pumps and absorber plates.

1. Using three pieces of swaged tubing and the straight pieces of the same diameter from Lab 10:
   a. Clean the copper using emery cloth, and apply flux to the joints.

2. Soft solder the three joints, using 50-50 solder on one joint, 6-40 on another and 95-5 on the last.

3. Using a hacksaw, cut through the three joints at a 45° angle. Using a pair of pliers, peel off the exterior portion of the copper and inspect your solder joints.

4. Have the lab attendant evaluate your work.

5. Select three other sets of swaged joints from Lab 10. Clean, flux, and silver solder these joints.

6. Have your work evaluated by the lab attendant.

7. Using 3" lengths of copper tubing and appropriate copper coupling fittings, silver braze three joints using Sil-phos 15.

8. Have your work evaluated.

Lab 12: Material Coatings, Material Compatibility

The compatibility of materials is a criterion that cannot be overlooked in fabrication processes. The physical and chemical properties of coatings must be considered when choosing a product and a process for finishing, particularly in the absorber plate.

1. Obtain three tin cans capable of holding slightly more than 1 lb. of water (1 pint) and **label** them on the interior surface with a permanent Mark-a-Lot marker (A, B and C).

2. Paint the exterior of each can with a coating - flat black lacquer - using the following procedures:
   a. One can with no treatment of the exterior.
   b. One can with the exterior surfaced cleaned using emery cloth or steel wool.
   c. One can cleaned as in B above and a coat of primer paint applied prior to the flat black.

3. After the paint has dried sufficiently, about 30 minutes, scratch the painted surfaces lightly with your fingernail.

4. Which of the cans was the most resistant to paint peeling? Which was the least resistant?

5. What conclusions can be drawn from the results in 4 above?

6. Using two of the three cans, paint one red and one blue.

7. Fill the three cans with an equal measured amount of water, as close to one pound as is possible. Place a thermometer in each can of water.

8. Place the cans of water in bright sunlight, side by side (if the sun is not shining, use a 1000 watt halogen quartz light with the heat evenly distributed on the cans).

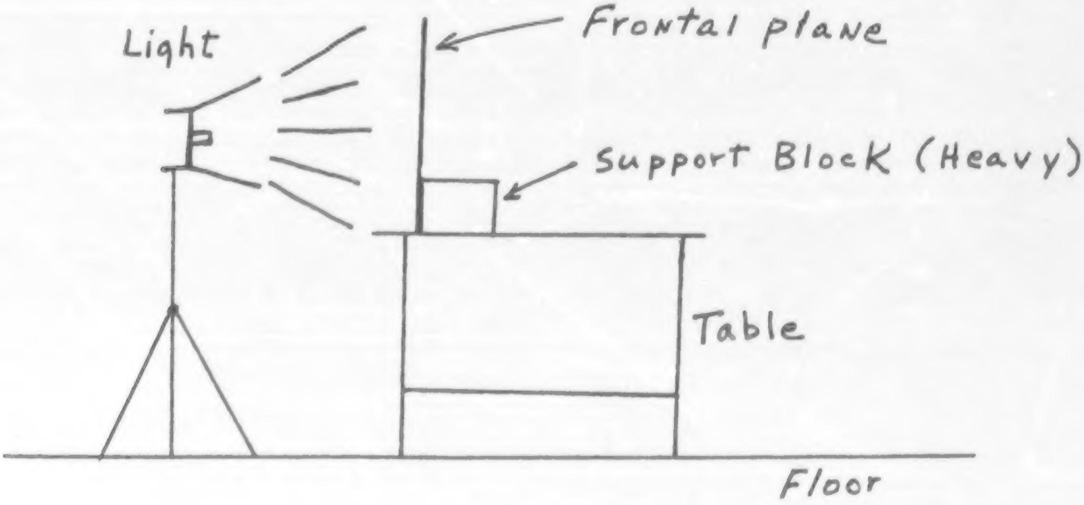
9. Record the water temperature at 3 minute intervals over 15 minutes.

10. Which coating was the best absorber of light energy?

11. What conclusions can be drawn from the above data?

The choice of glazing material is one that is dependent upon many variables as indicated in the glazing worksheets. This lab will demonstrate two of those variables, transmittance and reflection.

1. Set up a high intensity light and two choice of glazing per sketch below. The support block should be secured to table or something heavy enough that it will not move easily.



2. Place the light 1-3 feet from the frontal plane. Place a solar meter (Photo cell) scaled to measure Btu/ft^2/hr. and/or Langley's/hr. flush with the frontal plane.

3. Turn on the light and record the amount of light energy available at the meter.

4. Place a piece of glazing material (common window glass) in front of the meter, as close to the meter as possible and record the amount of light energy transmitted through the glazing.

5. Move the meter to the light side of the glazing and record the amount of energy reflected from the glazing.

6. Repeat steps 4 and 5 using different types of glazing material, i.e., F.R.P., acrylic, water white glass, etched glass, etc.

7. What conclusions can be drawn from the recorded data in this experiment?

Lab 14: Insulation

Insulation is the material that retards heat flow and thus is a vital component of any solar system. Primary uses are in structures, tanks, pipes, collectors, etc. Insulation keeps heat in as well as out in that it is a thermal barrier. Different types of insulating material have different thermal properties and the decision is usually a result of comparing thermal properties and cost to the application requirements.

1. Using the cans and thermometers from Lab 12, place an equal amount of water in each of the three cans. Bring the water temperature up to a stable 120°F in each can.

2. Quickly remove the cans from the heat source and wrap two types of insulating material around two of the water cans while leaving the third can bare.

3. Record the water temperature in each can at 3 minute intervals for 15 minutes.

4. Which can of water had the lowest heat loss coefficient? Which had the highest?

5. Repeat steps 1-3 for each of the three cans using the same type of insulation, but different thicknesses, i.e., 1", 2" and 3".

6. What conclusions do you draw from the recorded data?

Lab 15: Electricity

Installation of Solar systems also requires skills in electrical control systems and wiring techniques. Skills in electrical schematic diagrams are developed in other courses; however, the student does need to be proficient in interpreting pictorial diagrams, selecting wire sizes, installing terminal ends and connectors. This lab will require a training board similar to the one shown on the following page.

1. Follow the pictorial diagram and make all wire connections shown.

2. Use an ohm meter to determine if there is a load for the circuit. If the meter shows a short circuit, correct this condition before connecting to potential source.

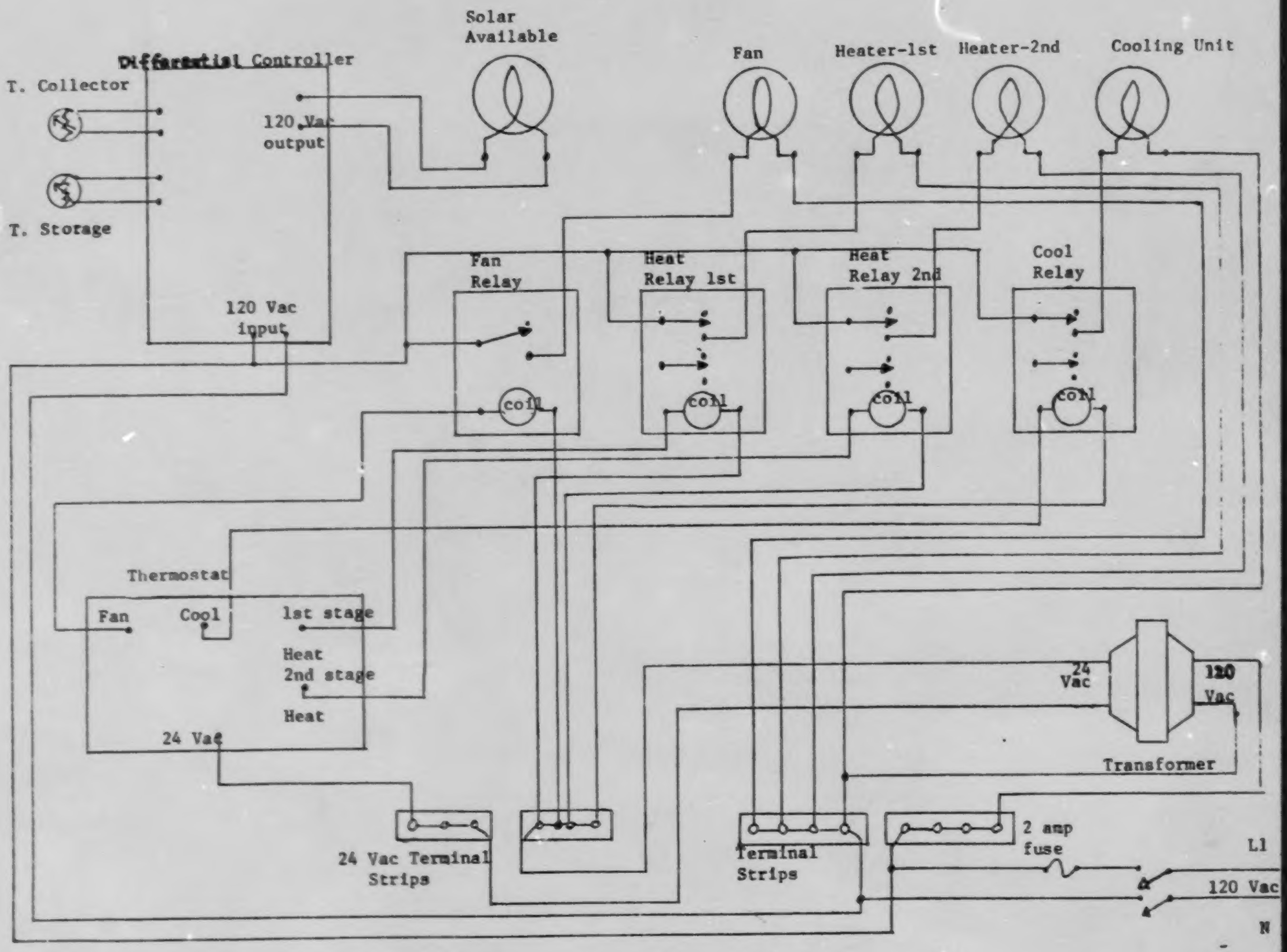
3. Have your work evaluated.

4. Using cups of hot and cold water for the collector and storage sensors, put the solar controller through the modes of operation.

5. Using the room thermostat, move through the other modes of operation.

6. Have the lab attendant evaluate your work for proper sequencing.

Lab 15
Page 2


Solar Available
Differential Controller
T. Collector
T. Storage
120 Vac output
120 Vac input
Fan
Heater-1st
Heater-2nd
Cooling Unit
Fan Relay
Heat Relay 1st
Heat Relay 2nd
Cool Relay
coil
coil
coil
coil
Thermostat
Fan
Cool
1st stage
Heat 2nd stage
Heat
24 Vac
24 Vac
120 Vac
Transformer
24 Vac Terminal Strips
Terminal Strips
2 amp fuse
L1
120 Vac
N

MATERIALS, MATERIAL HANDLING, AND FABRICATION PROCESSES

Representative Pre-Tests and Post-Tests

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

GENERAL SHOP SAFETY

SELF-TEST

1. What is the definition of the word "Accident"?

2. What percentages of accidents are considered as being "Natural Phenomena"?

3. What are five rules of good housekeeping?

4. What type of clothing should not be worn around operating mechanical equipment?

5. What type of wrench is first choice when it is at all possible to use it?

6. What is the ratio of hammer accidents as compared to handtool accidents?

7. How much cushion space should be maintained between the top of your head and the inside crown of your safety hat?

8. What are the four classifications of fires and what determines each class?

9. What type fire extinguisher must always be used on electrical fires?

10. What is considered to be the minimum electrical voltage which will cause death by electrocution?

11. What is the first precaution to observe if you are required to work on an energized electrical circuit?

12. What factor is the "killer" in electrical shock?

13. Can 100 volts be fatal to the average person?

14. What is the amount of current and the time of application to produce a fatal electrical shock?

15. What is the purpose of grounding electrical equipment?

16. Name at least four items of protective clothing or safety equipment.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

Select safety rules for using soldering and welding equipment by placing an "X" beside them in the blank space.

_____ a. Do not weld in the vicinity of explosive materials or near carbon tetrachloride.

_____ b. Always make sure you have enough ventilation to give three or four complete changes of air per day.

_____ c. Use air exhaust at the weld whenever welding lead, cadmium, chromium, manganese, brass, bronze, zinc, or galvanized metals.

_____ d. Never use a torch that leaks.

_____ e. Never leave your torch burning unattended.

_____ f. Never leave torch valve open.

_____ g. Do not use the torch for a hammer, crowbar, wedge, or for any purpose other than welding; do not use a cylinder, even when empty, as a roller.

_____ h. Do not use oil or grease on any oxygen or acetylene connections.

_____ i. Never open tank valves until you are certain that regulator valves are open.

_____ j. Open the valves on the cylinders with a hammer.

_____ k. Always wear suitable protective clothing.

_____ l. Always keep a safe, clean work area.

_____ m. Make sure there are no flammable materials near.

_____ n. Before lighting torch, be positive that hose, tanks, or any inflammable material will not be exposed to heat, flame, or sparks.

_____ o. Beware of high acetylene pressure; never use acetylene gas when the pressure is greater than 15 lbs. p.s.i.

_____ p. Do not store cylinders in a room where the temperature is less than 80 degrees.

_____ q. Do not adjust, alter, change, build, or do any experimental work on cylinders, regulators, torches, or any other gas equipment.

_____ r. Always weld a closed or jacketed tank, vessel, or container without a vent for air.

_____ s. Never hammer on oxygen or acetylene regulators.

_____ t. Do not light a torch with a match or open flame; use striker.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

Answer yes or no to the following:

_____ u. Can the polarity switch on the welding machine cause a burn hazard to the welder?

_____ v. Can the use of cables which are too small reduce the efficiency of a weld?

_____ w. Can welding on containers which have been used to hold solvents be dangerous?

_____ x. Does the color of the clothes worn by a welder have any effect on safety?

_____ y. Should a welder make temporary repairs on the welding machine so that he/she can continue welding until an electrician can repair the machine?

_____ z. Is it all right for a welder to watch the arc welding process for a few seconds at a time without eye protection?

_____aa. Should defective equipment be used until new or repaired equipment is available?

_____bb. Do welding machines need to be grounded for safe operation?

_____cc. Can working in a damp area affect the safety of the welder?

_____dd. Can a cracked hood lens have any effect on the welder's eyes?

_____ee. Should a welder know how to use fire extinguishers or are they someone else's responsibility?

_____ff. When two arc welding machines are in operation, can the electrodes be touched together?

_____gg. Is the welder responsible for warning the others in the area before striking an arc?

_____hh. Should the welder leave equipment on the floor around the job until the work is finished?

_____ii. Is it safe to handle non-insulated cables and clamps on the welding machine?

_____jj. Is a rule listed which limits the distance that combustible materials must be kept from the welding area?

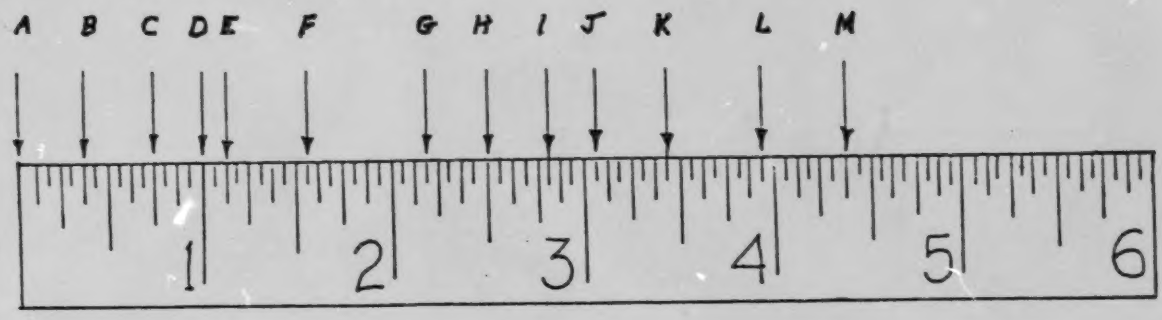
_____kk. Is good ventilation a part of the safety rules for a welder?

TEST: MATERIALS, MATERIALS HANDLING, AND
FABRICATION PROCESSES

UNITS OF MEASUREMENT AND MEASURING DEVICES

EXAM

Read the following measurements and fill in the blanks with the distance shown by the letter.



1. A to B _____

2. A to C _____

3. A to D _____

4. A to E _____

5. A to F _____

6. A to G _____

7. A to I _____

8. A to K _____

9. D to H _____

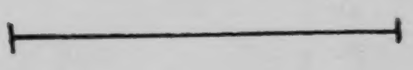
10. D to J _____

11. D to L _____

12. D to M _____

Measure the following lines to the nearest 1/16 of an inch.

13.



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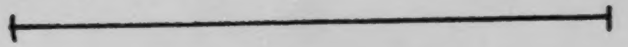

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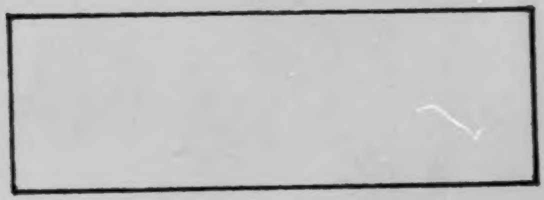
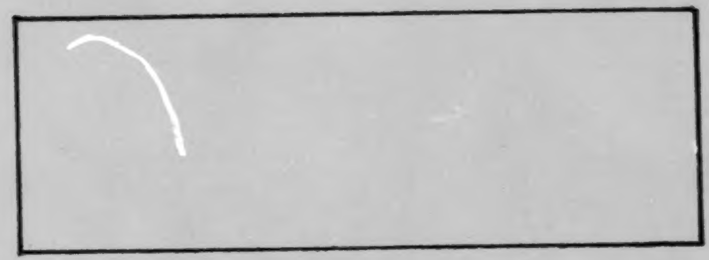


a. Length ______________

b. Width ______________

16.

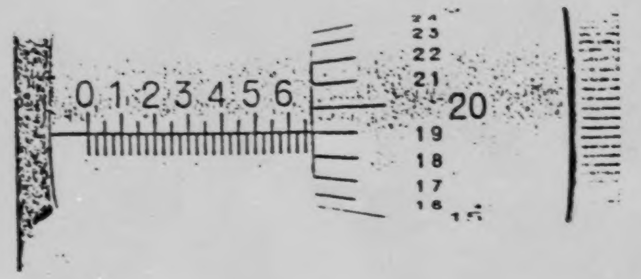


a. Length ______________

b. Width ______________

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

Record the micrometer reading in the space below each graphic.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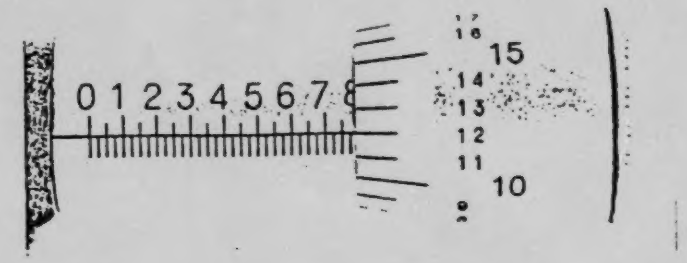
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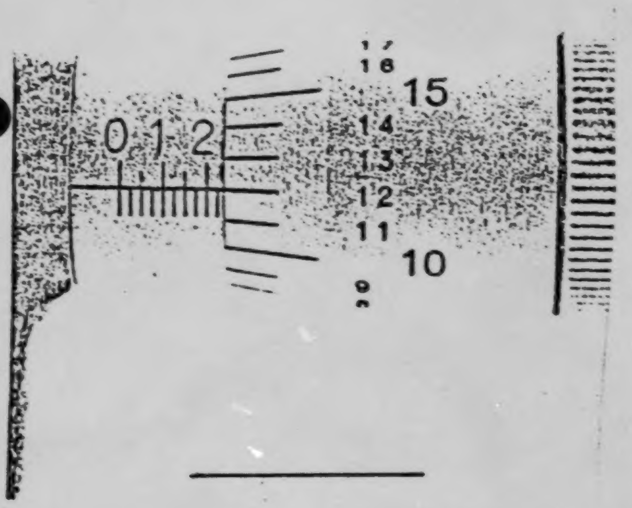
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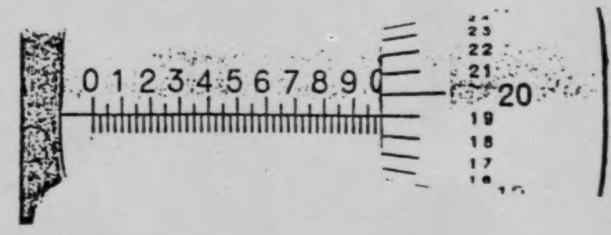
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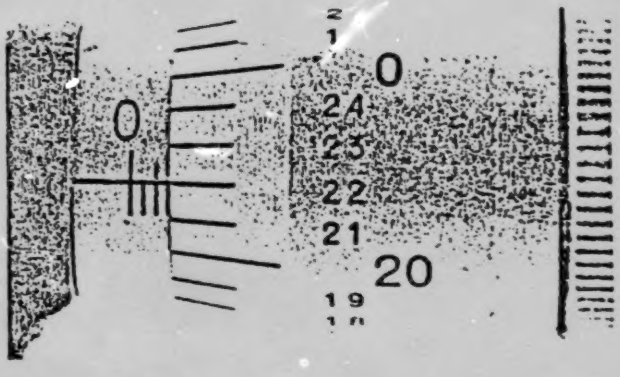
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TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

HAND TOOLS/POWER TOOLS

1. Match the illustration of each tool with its name.

_____ 1. Hand plane

_____ 2. Bolt cutter

_____ 3. Hatchet

_____ 4. Straight claw hammer

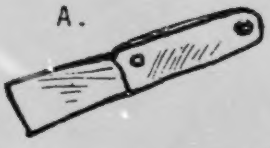
_____ 5. Curved claw hammer

_____ 6. Shop hammer

_____ 7. Utility knife

_____ 8. Putty knife

A.



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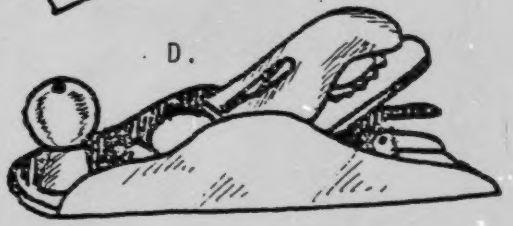

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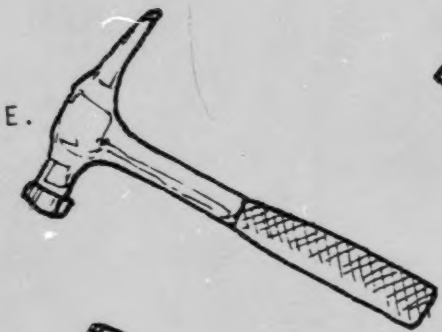

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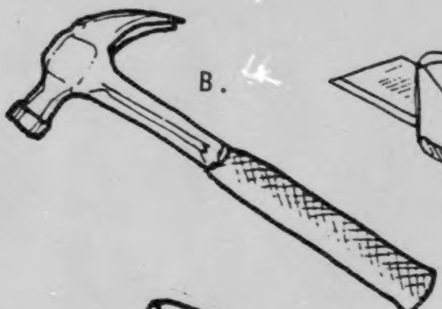

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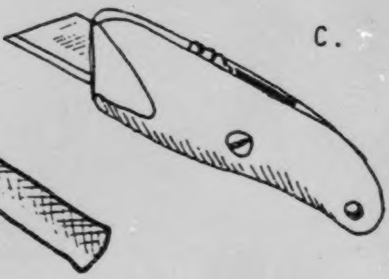

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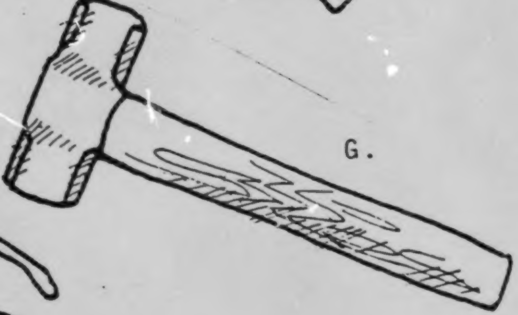

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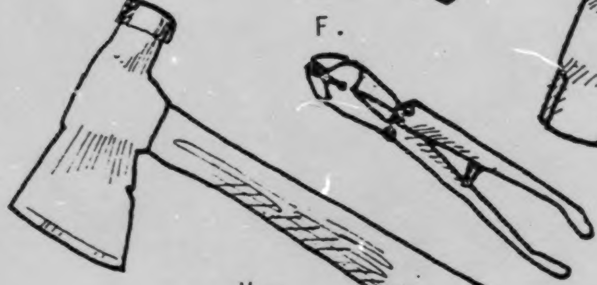


H.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

2. Match the illustration of each tool with its name.

_____ 1. Keyhole saw

_____ 2. Hand saw

_____ 3. Pry bar

_____ 4. Nail claw

_____ 5. Hacksaw

_____ 6. Side cutter pliers

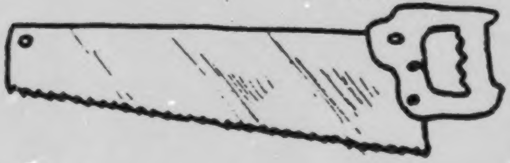
_____ 7. Chalk line and reel

_____ 8. Tin snips

_____ 9. "C" clamp

_____ 10. Adjustable wrench

A.



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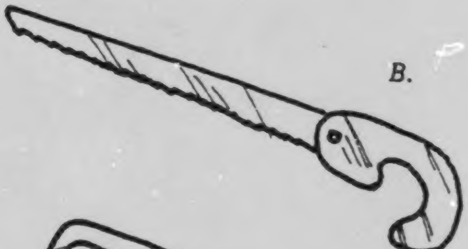

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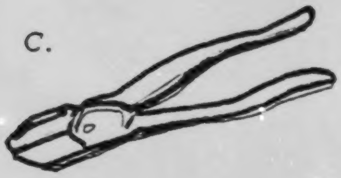

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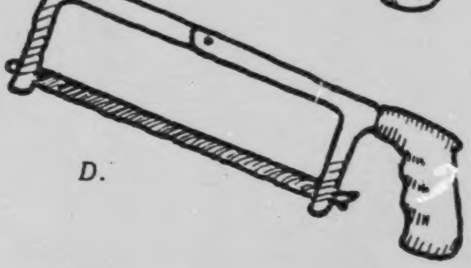

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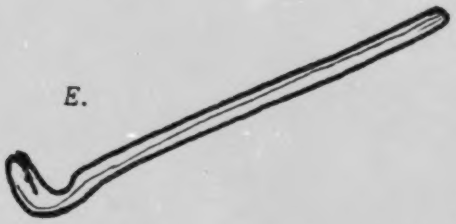

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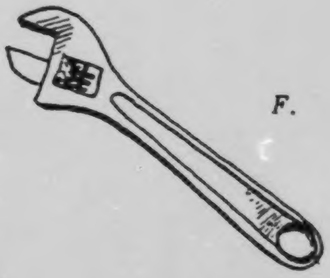

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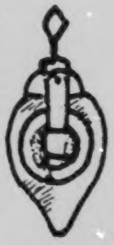

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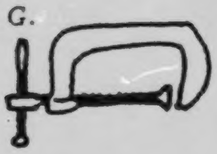

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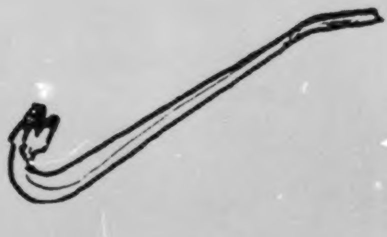

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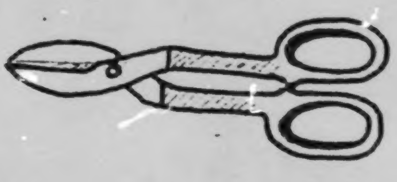


3. Match the illustration of each tool with its name.

_____ 1. Plumb bob

_____ 2. Carpenter's level

_____ 3. Torpedo level

_____ 4. Wood chisel

_____ 5. Wood rasp

_____ 6. Carpenter's brace

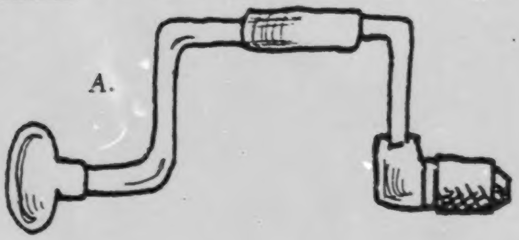
_____ 7. Speed bit

_____ 8. Star drill

_____ 9. Nail set

_____10. Wood bit

A.



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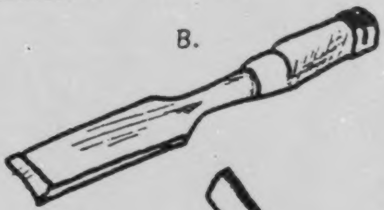

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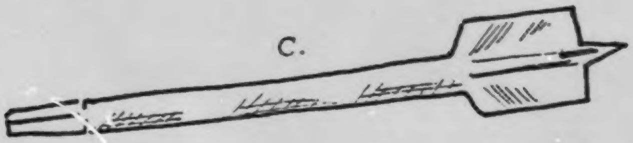

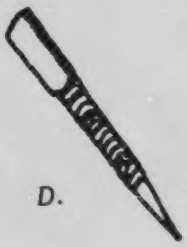

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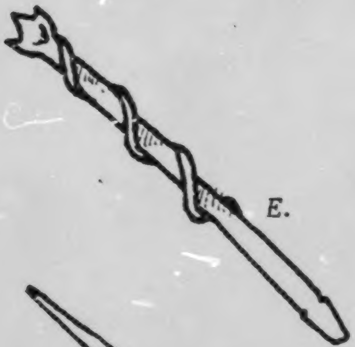

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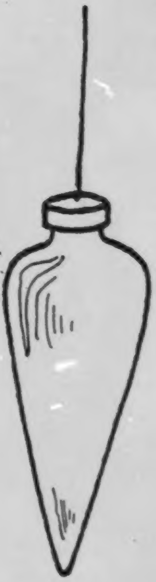

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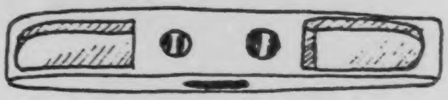

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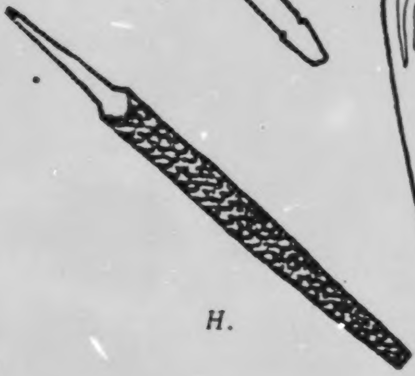

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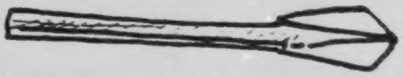
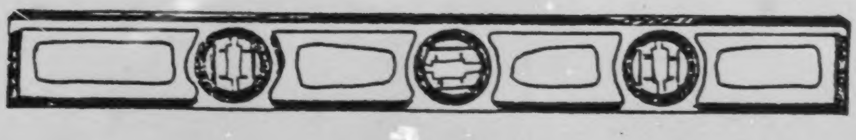




I.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

4. Match the names of hand tools with the description of their use. Write the letter in the space provided.

a. Curved claw hammer
b. Wood rasp
c. Plumb bob
d. Shop hammer
e. Straight claw hammer
f. Carpenter's level
g. Adjustable wrench
h. Carpenter's brace

i. Torpedo level
j. Side cutter pliers
k. Hatchet
l. Speed bit
m. Handsaw
n. Bolt cutter
o. Pry bar

Tool Uses

____ 1. For tightening bolts of various sizes

____ 2. Smooths wood edges and surfaces

____ 3. For cutting wire

____ 4. Holds drill bits used for drilling holes in wood

____ 5. Bores holes in wood

____ 6. Can be used to pull nails and for dismantling forms

____ 7. For general woodcutting use

____ 8. Is nine inches in length — used for obtaining level surface

____ 9. Used for vertical alignment

____10. Used for driving stakes

____11. Cuts bolts

____12. For dismantling and wrecking

____13. For obtaining a level surface

____14. Drives nails, draws nails, and sharpens stakes

____15. For driving nails, drawing nails, and used as a wedge for prying wood apart

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

5. Match the names of hand tools with the description of their use.

a. Block plane
b. "C" clamp
c. Hacksaw
d. Keyhole saw
e. Star drill
f. Wood bit
g. Putty knife
h. Wood chisel
i. Nail set
j. Chalk line and Reel
k. Tin snips
l. Nail claw

Tool Uses

____ 1. Used for applying putty

____ 2. Drives nails to a level below surface of the wood

____ 3. Marks a straight line on any surface

____ 4. Cuts sheet metal

____ 5. Holds items together and used for form alignment

____ 6. Used with a hammer for cutting grooves in wood

____ 7. Bores holes in concrete

____ 8. Bores holes in wood

____ 9. For cutting metal items

____10. Pulls large nails from wood

____11. Cuts curves and round holes in wood

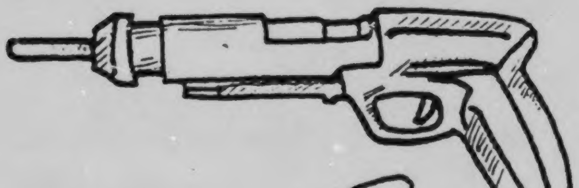
____12. Used for smoothing edges on wood

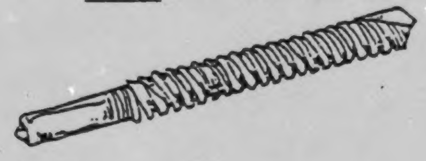
TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

6. Match the following illustrations of power tools and accessories with their names.

_____ 1. Electric hand saw
_____ 2. Powder actuated gun
_____ 3. Drive pin
_____ 4. Reciprocating saw
_____ 5. Saber saw
_____ 6. Radial arm saw
_____ 7. Electric drill
_____ 8. Table saw
_____ 9. Masonry drill bit
_____10. Metal drill bit
_____11. Band saw
_____12. Power masonry drill

A.





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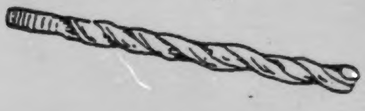

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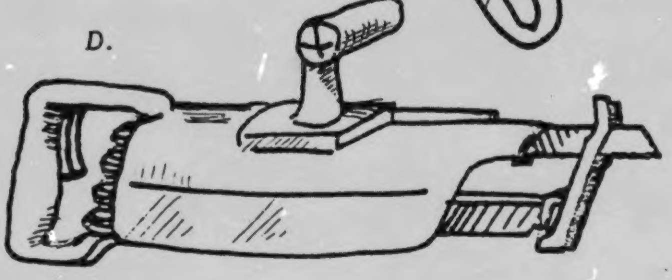

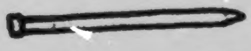

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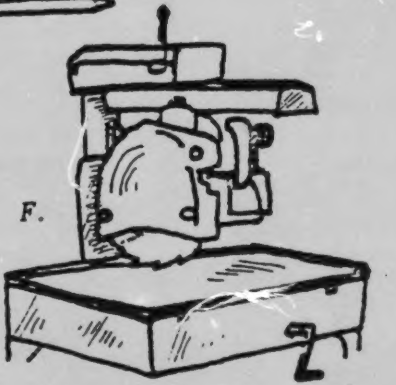

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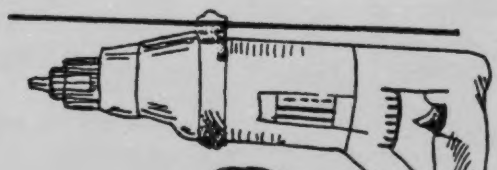

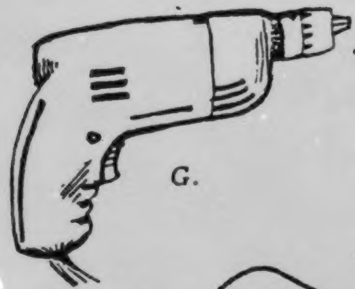

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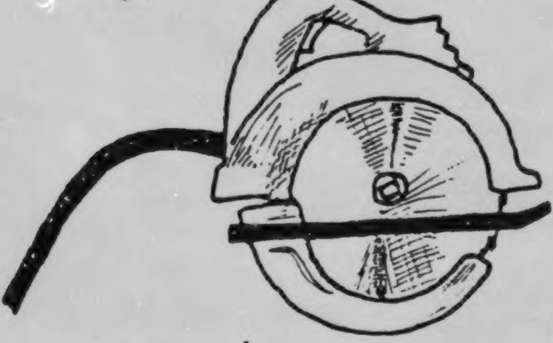
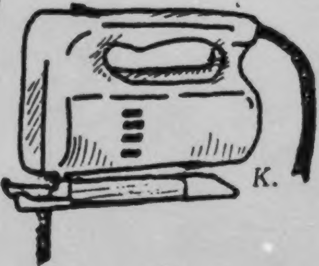


I.



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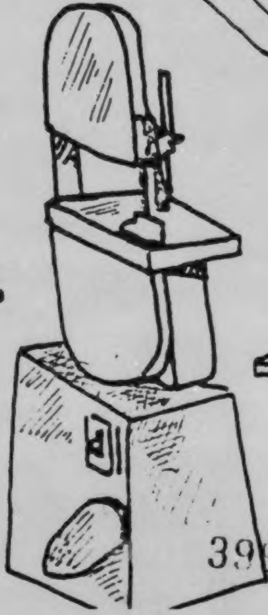
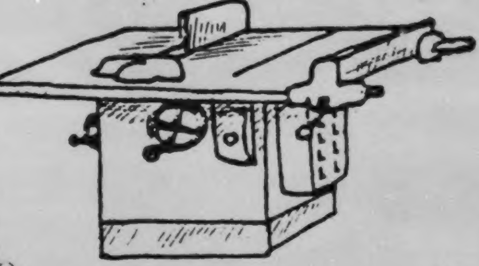


J.



L.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

7. Match the names of the power tools and accessories with the description of their use.

a. Saber saw
b. Band saw
c. Radial arm saw
d. Electric hand saw
e. Table saw
f. Reciprocating saw
g. Electric drill
h. Powder actuated gun
i. Drive pin
j. Masonry drill bit
k. Metal drill bit
l. Power masonry drill

Tool Use

_____ 1. Drives pins, studs, and nails in concrete

_____ 2. Drills holes in concrete or masonry

_____ 3. Along with powder actuated gun, fastens wood or steel to concrete

_____ 4. Tool which holds bit for drilling through masonry and concrete

_____ 5. Drills holes in wood or metal

_____ 6. Cuts curved or irregular patterns in wood

_____ 7. Portable tool for crosscutting and ripping lumber

_____ 8. Floor-mounted saw for cutting lumber

_____ 9. Holds drill bits for drilling holes in wood or metal

_____ 10. Floor-mounted saw with a track-mounted blade for cutting lumber

WELDING

SELF-TEST

1. The hose assembly, torch handle and regulator valve for an oxy-acetylene rig has left hand threads on the __________ (oxygen, acetylene) fittings.

2. What is the purpose of the oxygen stream in the center of the torch cutting tip?

3. What is the safety requirement in transporting the oxy-acetylene tanks?

4. The acetylene cylinder valve should never be opened more than __________ turn and the key should be left __________ the valve.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

5. The working acetylene pressure should never exceed __________ p.s.i.g.

6. Too much acetylene gas in the torch flame results in a __________ flame. Too much oxygen in the flame results in an __________ flame.

7. The most desirable position for welding is the __________ position.

8. Draw a sketch of the three most frequently used motions for weaving a bead (arc welding) in the flat position. Label each motion.

9. Why should pieces be tack welded before a weld is made?

10. Define the term penetration. Why is good penetration important to a good weld?

11. Why is a horizontal and vertical position weld more difficult than the flat position weld?

12. Draw a sketch and label these three common weld joints (Show the welded areas) -- Butt weld, lap weld and tee weld.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

13. What does the code number E-6011 (arc welding electrode) mean?

14. When one bead runs over the top of another, why is it necessary to clean the slag from the first bead?

15. List the personal safety clothing and equipment required for welding (Both oxy-acetylene and arc welding).

TEST: MATERIALS, MATERIALS HANDLING, AND
FABRICATION PROCESSES

CARPENTRY

SELF-TEST

1. Identify the following woods as Softwood or Hardwood in the space provided:

   A. Maple ____________

   B. Oak ____________

   C. Fir ____________

   D. Birch ____________

   E. Pine ____________

   F. Spruce ____________

   G. Ash ____________

2. Why does one need to be concerned about moisture content of lumber?

3. A stack of lumber has 24 pcs. 2" x 4" x 10′ long. How many board feet in the stack?

4. The lumber in question 3 sells for $560/1000 board feet. What is the cost of the 24 pcs.? ____________

5. A piece of plywood is described as being 5 ply, grade C-D. What does this description tell you about the plywood?

6. A hand saw is commonly available in two types. What are these types?
A. ________________________ B. ________________________

7. In saw terminology, what does the term "8-point" mean?

8. What is the purpose of the Mitre Box Saw?

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

9. The Radial Arm Circular Saw is used primarily as a __________ saw.

10. A hand ripsaw is designed to cut __________ the grain of the wood.

11. A __________ cuts a funnel-shaped recess to receive the head of a flat head screw.

12. A brace is used to hold the __________ and provide __________.

13. Auger bits range in size from __________ to __________ inches.

14. The most common metal fasteners used in carpentry are __________ and __________.

15. Why should nails be driven at a slight angle?

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

SHEET METAL

SELF-TEST

1. The most commonly used material in the sheet metal shop is:

   A. Copper

   B. Steel

   C. Tin plate

   D. Chromium

2. The protective coating on galvanized sheet metal is __________.

3. Stainless steel, though high in cost, is a desirable sheet metal for many applications because of its inherent resistance to __________.

4. Which of the following gauges of sheet metal is the thickest?

   A. 8

   B. 10

   C. 20

   D. 24

   E. 30

5. A sheet of galvanized steel, 4′ x 8′ x 28 ga., would weigh __________ pounds.

6. 16 gauge copper is __________ inches thick.

7. Why is it necessary to layout the flat pattern for a sheet metal project before beginning construction?

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

8. Define and describe the purpose of the sheet metal term "hem".

9. What is a common use of the dove tail seam in solar applications?

10. Name at least three methods of joining pieces of sheet metal.

ROOFING/FLASHING/PITCH PANS

SELF-TEST

1. What is the procedure for anchoring the collectors (or supporting structure) directly to the roof joints?

   A.

   B.

   C.

   D.

   E.

   F.

2. Roof penetrations may be sealed from the weather through the use of:

   A. Roof vent stacks

   B. Pitch pans

   C. Soldered flashing washers

   D. Rubber boots

   E. All of the above

   F. None of the above

3. The most difficult roof to seal against leaks through roof penetration is:

   A. Hip roof

   B. Gable roof

   C. Butterfly roof

   D. Flat roof

4. Define:
   A. Roof slope -

   B. Roof pitch -

5. The strength and rigidity of Roof truss construction uses the principle of the __________.

6. Draw a sketch of the approved nailing pattern for three tab square butt shingles.

7. What is the purpose of roof flashing? Why is it necessary around flush mounted collectors?

8. Describe the nails commonly used to apply asphalt roofing.

9. Saturated felt roofing materials is usually used as an under-layment on asphalt shingle roofs.

   A. True

   B. False

10. Draw a sketch of the J-Bolt Collector mounting method, including the pitch pocket.

SOLDERING

SELF-TEST

1. What is the melting point of 95-5 solder?

   A. 452-464

   B. 1140-1150

   C. 1300-1550

   D. 1775-2250

2. Why do you use flux on soft solder or silver solder joints?

   A. make a pretty joint

   B. keep solder from turning green

   C. prevent oxidation

   D. keep the joint from rusting

3. How much wire solder is needed to make a good solder joint?

   A. 1/4-1/2 the diameter of the pipe

   B. 1/2-3/4 the diameter of the pipe

   C. two times the diameter of the pipe

   D. none of the above

4. What is the flow point of Sil-phos?

   A. 452-464

   B. 110-1150

   C. 1300-1550

   C. 1775-2250

5. Which makes the strongest joint?

   A. soft soldering (using 95-5)

   B. silver brazing (using Sil-phos)

   C. silver soldering (using silver solder)

6. When speaking of 95-5 soft solder, what does the "95" mean, and what does the "5" mean?

7. What will happen when you apply too much heat to the joint when you are soldering?

8. What is the purpose of the flux when performing the soft-soldering process?

9. Why is a soft-solder joint to be cleaned after soldering?

10. To which part of the joint should the flux be applied when soft-soldering? To the male or female part of the joint?

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

11. In using Sil-phos for silver brazing, is it necessary to use a flux when joining copper to copper tubing?

12. What type flux should be used when silver soldering?

13. To which end of a sweat joint should the torch be moved once the tubing has reached the melting point of the silver solder?

14. How can one tell when the correct silver brazing temperature is reached?

15. What is the usual amount of silver content in silver solder?

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

PIPING PRACTICES

SELF-TEST

1. What is the name of the fitting that is used to join two pieces of galvanized pipe running in a straight line?

   ____

2. In galvanized piping where piping may need to be disassembled or taken apart at a later time, a ____________________ is placed in the line.

3. What type tubing would be used where corrosion is a possible problem? ____

4. What two types of flare nuts are used in solar installations?

   1. ________________________ 2. ________________________

5. What type of brass fittings are used to join two pieces of copper tubing in a straight line?

   ____

6. What is the name of the fitting used to plug the end of copper tubing?

   ____

7. What are the three methods of joining copper fittings to copper tubing?

   1. ________________________ 2. ________________________

   3. ________________________

8. What are the two types of copper slip fit ells?

   1. ________________________ 2. ________________________

9. What is the name of the copper fitting used to turn copper tubing 180 degrees?

10. What two type benders are used to make bends in copper tubing?

    1. ______________________

    2. ______________________

11. What is the name of the bender to make long radius bends?

    ____

12. If you were bending 3/8" copper tubing using a spring bender, what is the minimum radius the bend should have?

    ____

13. What bender must be used to make short radius bend?

    ____

14. If you had a 1/2" copper tubing with a 3" radius 90 degree bend, how much should you allow for the bend allowance?

    ____

15. What two types of dimensions must be added together to find the total length of copper tubing needed?

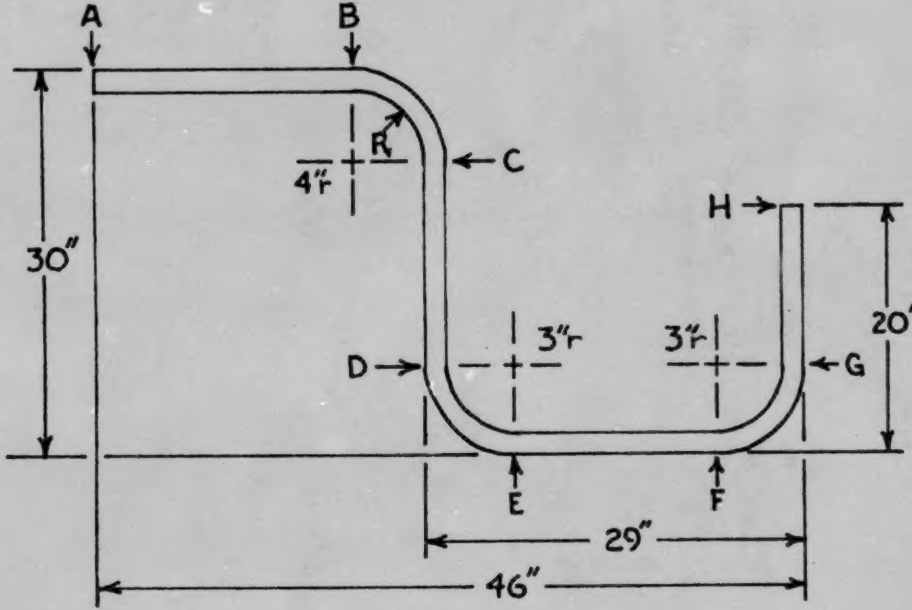
    1. ______________________

    2. ______________________

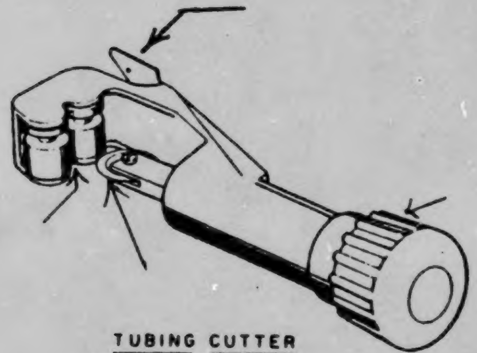
16. Using the drawing on the next page, find the amount of straight line length of copper necessary to make the configuration.

    ____

Drawing


A
B
C
D
E
F
G
H
R
4"r
3"r
3"r
30"
20"
29"
46"

17. Identify the parts of the tubing cutter in the drawing below.



TUBING CUTTER

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

18. What precautions should be used when using a hacksaw to cut copper tubing?

19. Why should the flare nut be placed over the tubing before flaring?

20. When swaging a 3/8" OD copper tubing, how deep should the socket be?

21. What may be the results if you drive a swaging tool all the way down into the holding block?

22. During the swaging process, the copper tubing gets longer or shorter?

23. What should be done to the copper tubing before the cutting process begins?

24. After you have made 2 - 5 turns with the tubing cutter around the tubing, how much should the lead screw knob be turned?

25. What will be the result if one forgets to back off the handle during the flaring process?

26. Which P.V.C. pipe can withstand greater pressure? Schedule 40 or 80.

27. What is the process used in joining P.V.C. pipe and fittings?

28. P.V.C. piping is a good choice for medium temperature solar systems. True or False.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

GLAZING MATERIALS

SELF-TEST

1. What is the function of glazing in a solar collector?

2. What are the three desirable characteristics of a glazing?

3. For good performance over an extended period of time, a glazing must have three characteristics. What are they?

4. Which glazing material, glass or filon, has the higher coefficient of linear expansion? ________________________

5. What is the principal problem with using glass as a glazing for collectors? How can this problem be minimized?

6. The glazing worksheet lists 10 physical and chemical properties that must be considered when making a glazing choice. What are they?

7. What is meant by the term "UV degradation"; and how does this phenomenon affect glazing performance?

MATERIAL COATINGS AND COMPATIBILITY

SELF-TEST

1. Other than painting, what three processes are commonly used in coating metals?

   A. ____________________

   B. ____________________

   C. ____________________

2. What is the purpose of the absorber coating in solar collection systems?

3. Describe how a selective surface coating improves absorber performance.

4. Name three selective surface coatings.

   A. ____________________

   B. ____________________

   C. ____________________

5. How does material compatibility affect the coating choice?

6. Metal piping is sometimes incompatible with other metals and fluids. Explain why and describe recommended corrective actions.

INSULATION

SELF-TEST

1. Heat is transferred through walls, floors, ceilings, etc. at a rate directly related to the ____________ in temperature and the ____________ to heat flow provided by the intervening materials.

2. The three methods of heat transfer are:

   A. ____________________

   B. ____________________

   C. ____________________

3. A good insulating material will have a (high, low) ____________ R. value.

4. Define U factor.

5. An insulating material having a K factor of .22 would have an R value of ____________.

6. A wall structure of face brick veneer, 3/8" plywood, 3 1/2" flexible fiberglass, and 1/2" sheet rock would have an R value of ____________ and a U factor of ____________.

7. The insulation worksheet directs attention to eight chemicals and physical properties of insulation that must be considered in making a choice. What are they?

8. How does wet insulation affect its ability to resist heat flow?

9. What component in fiberglass insulation causes outgassing?

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

ELECTRICITY

SELF-TEST

1. An electric circuit has 135 ft. of wire carrying 15 amps current. What size wire should be used?

   ____________ gauge

2. What would be the effect on the circuit if the next size smaller wire were used?

3. The recommended maximum voltage drop in a circuit is _____% at 240V.

4. Draw the schematic symbol for:

   A. Temperature actuated switch

   B. Normally closed push button switch

   C. Fuse

   D. Normally open contacts

   E. Normally closed contacts

   F. Relay coil

   G. Solenoid

   H. Transformer

5. What is the most common cause of blown fuses or tripped circuit breakers?

6. Define the following electrical terms.

   A. Voltage

   B. Current

   C. Resistance

   D. Circuit

   E. Circuit load

   F. Watts

7. Why are balanced circuits important?

8. What is the usual color code used in household wiring for:

   A. 120V

   B. 240V

9. Why are grounded circuits important?

10. The tool used to remove insulation from wire is called a ____________________.

TEST: MATERIALS, MATERIALS HANDLING, AND FABRICATION PROCESSES

11. What is BX cable?

12. In wiring a 120V receptacle the "hot" wire should be attached to the (silver, gold) ___________ colored screw.

13. Describe two common methods of joining two wires.

14. List the requirements for outdoor installations.

15. What type solder must be used in soldering wire? Why?

SYSTEM SIZING, DESIGN AND RETROFIT

Semester Hours Credit: 4
Lecture: 3
Lab: 3

Project Director:	Charles G. Orsak, Jr.
Prime Author:	Everet W. Bolin
Contributing Authors:	Alan Boyd Bob Takacs

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INTRODUCTION:

The Systems Sizing, Design and Retrofit course systematically presents the parameters and procedures necessary to develop skills in sizing and equipment selection for the components that make a Solar heating system. The major emphasis is toward residential space heating and service hot water; however, load calculations are done for residential cooling. Even though there has been tremendous improvement in equipment used in solar cooling, the present methods may not be cost effective for most residences. The further development of the Rankine-cycle system may change this posture, and test data from this system looks promising.

This course also presents methods of making life cycle cost analysis of systems, making the decision process easier. Also, start-up procedures and check lists are presented, along with operation and maintenance procedures for the systems.

COURSE DESCRIPTION:

This course presents systematic, detailed methods and procedures for sizing, selection, and installation of solar system components. It also develops skills required to analyze the complete, integrated system including controls and interface with auxiliary conventional systems. Thermal analysis, load calculations, human comfort and air properties are an integral part of the course.

COURSE PREREQUISITES:

(1) College technical math - 2 semesters.

(2) Collectors and Energy Storage and credit for or concurrent enrollment in Energy Science II.

(3) Technical drafting or equivalent drafting skills.

COURSE OBJECTIVES:

Upon completion of this course, the student should be able to:

(1) Determine system guidelines for quick estimation of costs.

(2) Calculate the system load for human comfort.

(3) Make a thermal analysis and life cycle cost analysis of the system.

(4) Apply design parameters and application considerations in the design procedure.

(5) Size and select appropriate system and subsystem components.

(6) Determine the feasibility of retrofitting a system.

(7) Effect operational and maintenance procedures for the system.

SYSTEM SIZING, DESIGN AND RETROFIT

MODULE INDEX

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Sizing and Selection of Collector Array-
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OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe building/site conditions that could affect design decisions.

(2) Decide which collector, storage, and subsystem types would be most appropriate for a given application.

(3) Select location options for collectors and storage vessels.

(4) Determine appropriate collector tilt angle.

(5) Recommend conservation measures that retard building thermal losses.

RATIONALE:

Before the design, sizing, and specific component selection process begins, there must be a basis for making decisions. This module presents the preliminary factors that must be considered before rational decisions can be made.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings: Design of Systems, U.S. Department of Commerce, 1977.

(2) Intermediate Minimum Property Standards Supplement - 493.2, U.S. Department of Housing and Urban Development, 1977.

(3) Dixon, A.E. and J.D. Leslie, Solar Energy Conversion, Pergamon Press, N.Y., 1979.

(4) Colorado State University, Solar Heating and Cooling of Residential Buildings: Sizing, Installation and Operation of Systems, U.S. Department of Commerce, 1977.

(5) Solar Training Manual, Phase I, Lennox Industries Educational Department, Dallas, Texas, 1979.

(6) Applications Engineering Manual, Solaron Corporation, Denver, Colorado, 1978.

(7) Solar Energy for Buildings Handbook, DOE-ORO-5362-T1.

V-8 MODULE: DESIGN CONSIDERATIONS AND PARAMETERS

UNIT TITLES:

(1) Preliminary Building/Site Considerations

(2) Preliminary Collectors Considerations

(3) Preliminary Storage Considerations

(4) Preliminary Subsystem Considerations

VOCABULARY:

- Building Site
- Plot Plan
- Building Orientation
- Roof Pitch
- Building Codes
- Property Covenants
- Zoning Regulations
- Energy Demand Patterns
- Degree Day Adjustment Factor
- Purge Coil
- Aesthetic Appearance
- Specific Heat
- Volumetric
- Stratification
- Circulation Circuit
- Heat Exchanger Terms
- Control Logic
- Temperature Set Point
- Expansion Tank

	Unit 1. Preliminary Building Considerations
Reference 1, Modules 5,8, & 9	A. Energy conservation measures - describe 1. "Insulation before insolation" 2. Weatherstripping and caulking 3. Thermal efficient glazing 4. Awning, shade, and overhang
Reference 2, Module 3 Graphic illustration of these topics Reference 7, pg. 105	B. Building site/orientation - discuss 1. North/south exposure 2. East/West exposure 3. Actual or potential shading from trees, buildings, etc. 4. Sun rights
Reference 2, Module 4 Demonstrate by illustration effects of these topics. Reference 7, pp. 107, 137-139	C. Building configuration - design decision factor 1. Roof pitch (angle) 2. Roof type 3. Collector mounting space a. Roof mounted b. Ground level 1. Distance from building 2. Damage potential 4. Storage space available a. Within building b. Above ground level c. Below ground level
Reference 3, pp. 555-586	D. Structural materials - effects on design 1. Type and mass 2. Load bearing capacity 3. Thermal properties and characteristics
Reference 1, Module 21	E. Codes, property covenants, zoning regulations or restrictions - what are they? Briefly
	F. Occupant utilization 1. Space usage a. High use areas b. Low use areas 2. Energy demand patterns

STUDENT ACTIVITY

Exercise

Laboratory/discussion:

Given a site plan, location (city, county, etc.) and building drawings, the student should:

1. List the building considerations that might affect the application(s) decision.
2. Decide which application(s) would be appropriate and give the rationale for the decision.

Alternate Exercise

Go to a residential building under construction and:

1. List the building considerations that might affect the application(s) decision.
2. Decide which application(s) would be appropriate and give the rationale for the decision.

Reference 1, Modules 8 & 9
Review material from these courses:
Intro to Solar Energy Collectors and Energy Storage

Unit 2. Preliminary Collectors Considerations

A. Building load - discuss
    1. High demand periods
    2. Low demand periods
    3. Available options
    4. Degree day adjustment factors
B. Determine energy cost - space heating, space cooling, and domestic hot water
    1. Previous years
    2. Present year
    3. Projected energy costs
        a. Next year
        b. 3 years hence
        c. 5 to 10 years hence
    4. Energy availability - which source?
        a. Present
        b. Future
C. Energy costs - domestic hot water
    1. Previous years
    2. Present year
    3. Projected energy costs
        a. Next year
        b. 3 years hence
        c. 5 to 10 years hence
    4. Energy availability
        a. Present
        b. Future

D. Energy costs - space cooling
  1. Previous years
  2. Present year
  3. Projected energy costs
    a. Next year
    b. 3 years hence
    c. 5 to 10 years hence
  4. Energy availability
    a. Present
    b. Future

E. Solar fraction - affects of these upon decision
  1. Physical limitations
  2. Economic limitations
  3. Efficiency parameters

F. Flat plate vs. concentrating collectors
  1. Compare application and efficiency
  2. Economics
  3. Controls required
  4. Maintenance required

G. Insolation available - discuss the affects upon decision
  1. Cloud cover
  2. Pollutants

H. Tilt angle required
  1. Space heating
  2. DHW
  3. Space cooling
  4. Compromises - rationale

I. Orientation
  1. Effect of deviation from solar south
  2. Compromises - rationale

J. Aesthetic appearance
  1. Neighborhood constraints
  2. Collector rack construction
  3. Collector rack finish

K. Rules of thumb for sizing array

STUDENT ACTIVITY

Exercise

Laboratory/Discussion:

Based upon decisions from Unit 1 Exercise and information from Unit 2 (this unit) the student should:

1. Decide which type collector would be best suited for the application(s).
2. Determine where they should be mounted.
3. Determine tilt angle required.

Reference 4, Module 6

Review material from these courses: Intro to Solar Energy, Collectors and Energy Storage, and Energy Science I & II.

Module 12 - Design of Systems.

Unit 3. Preliminary Storage Considerations

- A. Location
  - 1. Inside building
  - 2. Outside building
  - 3. Distance from collectors
  - 4. Above or below ground level
- B. Space requirements
  - 1. Liquid storage
  - 2. Rock storage
  - 3. Phase change materials
- C. Container construction
  - 1. Pressure requirements
  - 2. Material cost
  - 3. Availability of material
  - 4. Construction methods
- D. Heat storage materials
  - 1. Specific heat
    - a. Liquids
    - b. Stones
    - c. Phase change compounds
  - 2. Volumetric requirements
- E. Accessibility for maintenance/repairs
  - 1. Leaks and leak detection
    - a. Liquid
    - b. Air
    - c. Phase change compounds
  - 2. Component replacement/repairs
    - a. Liquid
    - b. Air
    - c. Phase change compounds
- F. Hygiene considerations
  - 1. Air
  - 2. Liquid
  - 3. Phase change compounds

- G. **Stratification requirements**
  - 1. Liquid system
  - 2. Air system
- H. Rules of thumb for sizing

STUDENT ACTIVITY

Assignment:

Using information and decisions from Unit 1 and 2 Exercises, the student should select the best storage method and heat storage fluid.

Reference 5, Equipment Selection Section
Reference 6, Section 300, 400, 500 and 800

Overhead transparency or chalkboard. Graphic illustrations of these various heat exchangers and flow patterns.
Reference 5, Equipment Section
Reference 6, Section 300

Unit 4. Preliminary Subsystem Considerations

- A. Circulation circuit considerations
  - 1. Piping
    - a. Size
    - b. Configuration
    - c. Fittings
    - d. Valves
    - e. Materials
  - 2. Ducts
    - a. Size
    - b. Configuration
    - c. Fittings
    - d. Dampers
    - e. Registers - supply and return
- B. Circulating device
  - 1. Pumps - what type, what size?
  - 2. Fans/blowers - what type, what size?
  - 3. Rules of thumb for sizing
- C. Heat exchangers - review
  - 1. Liquid/liquid
  - 2. Air/liquid
  - 3. Flow patterns
    - a. Liquid/liquid
    - b. Air/liquid
      - 1. Air flow
      - 2. Liquid flow
  - 4. Construction characteristics
    - a. Bare tube
    - b. Finned tube
    - c. Spiral tube
    - d. Flow baffles
    - e. Single wall
    - f. Double wall
  - 5. Availability of choices

6. Rules of thumb for sizing

D. Heat transfer fluids

E. Control systems
   1. Control logic (which method)
   2. Determine desired temperature swing - set points
      a. Collector
      b. Storage
      c. Ambient
   3. Controllers - what types, how many required
      a. Temperature
      b. Pressure
      c. Humidity
      d. Time
      e. Limit
   4. System energy source decision
      a. Electric
      b. Electronic
      c. Pneumatic
      d. Hydraulic
      e. Availability of choices

Graphics Appendix
PC-1 through PC-12

F. Protective devices - which ones? How many?
   1. Pressure relief
   2. Freeze protection
   3. Expansion tank
   4. Purge coil
   5. Drain down
   6. Drain back
   7. Air vents
   8. Filters

STUDENT ACTIVITY

Exercise

Assignment:

Using information and decisions from Units 1, 2, and 3, the student should select the appropriate subsystem and basic components of the subsystem.

Reference 1, Chapter 18

Brief description of the highlights of these procedures.

Unit 5. Survey of Detailed Design Procedures

A. Computer models
   1. Solcost
   2. Trynsis
   3. ASHRAE
   4. SIMSHAC
   5. **F-chart (See note below)**

Show TI-59, HP67, HP97 or similar models

B. Calculator methods
   1. Hand or desk calculator-programmable
   2. F-chart program

NOTE: This program will be utilized later in this Module

   3. Manufacturer's worksheet

Reference 1, Module 4
Reference 5, Equipment Selection Section, pp. 3-6

C. Manual calculations
   1. Huck-Winn method
   2. Balcomb-Hedstrom method
   3. Manufacturer's worksheet

NOTE: Most collector manufacturers provide short form worksheets for sizing the collector array. Reliability is questionable using the short form method. Lennox's long form method, which is a variation incorporating f-chart data is a reliable manufacturer's worksheet calculation method. Solaron's Air System worksheet is also a reliable manufacturer's worksheet method. The f-chart method is the most widely used procedure in the solar industry for system sizing and design; however, it is not without fault. It is also a very long, time intensive manual calculation method. The f-chart calculator program is reliable and fast.

Reference 2, Appendix A

Unit 6. Manual Sizing Procedures

NOTE TO INSTRUCTOR:

Suggest the students be given a printed handout of the f-chart manual method.

STUDENT ACTIVITY

Assignment:

Given the required building and design criteria, have the students work through the f-chart calculations so that they may better comprehend the calculations occurring during the f-chart program operations. Since this assignment will require some time, its assignment can be done outside the classroom while the manual sizing procedures are done in the classroom. Set due date appropriate for review and demonstration in the Module: Sizing, Selection, and Installation of the Collector Array - manual.

MODULE: LOAD CALCULATION FACTORS AND PROCEDURES

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Calculate R-factor and U-factors.

(2) Discuss the relationship of thermal conductivity, thermal conductance, and thermal resistance.

(3) Explain the meaning and use of Equivalent Temperature difference in load calculations.

(4) Calculate the rate of heat transfer for a given structure and geographic location.

(5) Discuss the role of human comfort, inside and outside, wet bulb and dry bulb temperatures in the load calculation process.

RATIONALE:

There are certain factors that are common to load calculations for residential applications. Before starting the thermal analysis for space heating/cooling and service water, a demonstratable knowledge of these factors and the load formula is essential.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings: Design of Systems, U.S. Department of Commerce, 1977.

(2) Kreith, Frank, Principles of Heat Transfer, Intext Publishers, N.Y., 1973.

(3) Load Calculations, Manual J., NESCA, Arlington, Va., 1975.

(4) Carrier Corp., Handbook of System Design, McGraw-Hill Book Co., N.Y., 1965.

UNIT TITLES:

(1) Heat Transfer - Review

(2) Thermal Properties of Materials

(3) Heat Transfer Coefficients

(4) Structural Load Calculation Process

(5) Other Gains or Losses

VOCABULARY:

Thermal Conductivity
C-Factor
R-Factor
Heat Transfer Coefficient
Equivalent Temperature Difference
Temperature Swing
K-Factor
U-Factor
Design Temperature
Degree Day
Btu/Hr.

Reference 3, Section 3 and 9
Reference 4, pp. 1-9 to 1-24
Graphics reference
Reference 1, pp. 5-5 to 5-11

Unit 1. Heat Transfer - Brief Review
- A. Methods of heat transfer
    - 1. Conduction
    - 2. Convection
    - 3. Radiation
    - 4. The evaporation process
- B. Mode of flow (hot or cold) - winter/summer

Reference 2, Chapter 1-8

Unit 2. Thermal Properties of Materials - Define and Give Examples
- A. Thermal conductivity
- B. Thermal conductance
- C. Thermal resistance
    - 1. $\frac{1}{K}$
    - 2. $\frac{1}{c}$
    - 3. $\frac{1}{K \div \text{thickness}}$

Reference 1, pp. 5-5 to 5-11

Unit 3. Heat Transfer Coefficients (U-Factor) - Calculate
- A. Resistance of homogeneous materials
- B. Resistance total of more than one material

$$\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_n}} = \text{U-factor}$$

- C. Effects of air films - inside and outside
- D. Effects of wind velocity
- E. Example U-factor calculations

Tables of ETD from Reference 3 or 4. Printed hand-out with overhead transparency

Unit 4. Structural Load Calculation Process
- A. Load formula - $Q = UA\Delta t$
- B. Equivalent temperature difference - discuss
    - 1. Walls
    - 2. Ceilings
    - 3. Roofs
- C. Design temperatures - determine
    - 1. Human comfort
        - a. Body as a heat machine
        - b. External factors
        - c. Comfort zone

2. Outside
    a. Dry bulb temperatures
    b. Wet bulb temperatures
3. Inside
    a. Dry bulb temperatures
    b. Wet bulb temperatures
4. Design temperature difference (TD)
5. Temperature swing - give parameters

D. Design temperature tables

E. Equivalent TD tables

F. Load calculation - structural
1. Btu/DD
2. Monthly requirements
3. Annual requirements

Reference 3, Section 9

Unit 5. Other Gains or Losses

A. Internal gains or losses
1. People
2. Electrical equipment
3. Kitchen appliances

B. Infiltration and ventilation air - determine amount

C. Latent heat - rule of thumb

D. Duct gain/loss

STUDENT ACTIVITY

Laboratory Materials and Tools:

Laboratory:

A building with walls of more than one material and insulation, thermometers; a table of building material R-values, K-values and C-values; Equivalent Temperature Difference Table and Design Temperatures.

Exercise:

1. The student should calculate the U factor for the walls.
2. Using the measured indoor temperature and the measured outdoor temperature, the student should calculate the rate of heat transfer.
3. The student should identify the direction of heat flow (outside to inside or inside to outside).
4. Assume one wall to be in sunlight, calculate the rate of heat transfer for that wall. Analyze the result.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Use appropriate tables of design temperatures, degree days, insolation.

(2) Identify factors that influence heat loss.

(3) Calculate thermal loads using worksheets, NESCA for J-1, and short form methods.

(4) Analyze the thermal losses of the building for efficiency.

RATIONALE:

The system sizing process continues. The methodology, used in designing the total system, is analyzed in a systematic manner.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings: Design of Systems, U.S. Department of Commerce, 1977.

(2) Handbook of Fundamentals, ASHRAE, N.Y., 1974.

(3) Carrier Corp., Handbook of System Design, McGraw-Hill Book Co., N.Y., 1965.

(4) Kreith, Frank, Principles of Heat Transfer, Intext Publishers, N.Y., 1973.

(5) Load Calculation, Manual J., NESCA, Arlington, Virginia, 1975.

(6) Lőf, George O. G., Design and Construction of a Residential Solar Heating and Cooling System, NSF GI-40457, NTIS, Springfield, Virginia, 1974, NSF-RA- N-74-104.

(7) Pickering, Ellis E., Residential Hot Water Solar Energy Storage Subsystems, NSF C-905, NTIS, Springfield, Virginia, 1976, NSF RA-N-75-0.

UNIT TITLES:

(1) Survey of Building

(2) Factors Influencing Heat Loss

(3) Calculation Procedure

(4) Thermal Analysis - Space Heating

VOCABULARY:

Transmission Loss
Design Temperatures
Blueprint
Sketch
Design Temperature Difference
Heat Transfer Multipliers
Storm Windows
Thermal Pane Windows
Single Pane Windows
Infiltration Air
Structural Losses
Internal Gains
Duct Loss
NESCA
Short Form
Storm Doors
Daily Load
Monthly Load
Annual Load
Ventilation Air

Reference 1, Module 5
Reference 3, Part 1
Reference 5, Section 1-7
Reference 1, pp. 5-23 to 5-29

Unit 1. Survey of Building

- A. Blueprint or sketch - examine
- B. Record data
  - 1. Building compass orientation
  - 2. Conditioned rooms
    - a. Floor area
    - b. Wall area - adjacent to unconditioned space
    - c. Doors and windows
      - 1. Location and type
      - 2. Area
    - d. Ceiling area
    - e. Roof area (if applicable)
  - 3. Outside design temperature
  - 4. Inside design temperature
  - 5. Degree days - heating
    - a. January
    - b. Annual
  - 6. Desired temperature swing
  - 7. Desired relative humidity
  - 8. Number of occupants
  - 9. Special activities
  - 10. Unusual latent heat sources
  - 11. Kitchen and electrical appliances
  - 12. Lighting

Reference 5, Section 3

Reference 3, Part 1
Reference 6, pp. 4-15
Reference 1, pp. 5-5 to 5-11

Unit 2. Factors Influencing Heat Loss - Explain Them

- A. Walls - exposed to outside
  - 1. Construction material
  - 2. Construction methods
  - 3. Insulation
  - 4. Below ground level
- B. Partitions - spaces at different temperatures
  - 1. Construction material
  - 2. Construction methods
  - 3. Insulation
  - 4. Below ground level
- C. Ceilings - exposed to unconditioned space
  - 1. Construction material
  - 2. Construction methods

    3. Insulation
    4. Below ground level
D. Floors - exposed to unconditioned space
    1. Above ground
        a. Construction material
        b. Construction methods
        c. Insulation
    2. Ground level
        a. Construction material
        b. Construction methods
        c. Insulation
    3. Below ground level
        a. Construction material
        b. Construction methods
        c. Insulation
E. Doors
    1. Weatherstripping
    2. Storm door
    3. Air locks
    4. None of above
F. Glass doors
    1. Weatherstripping
    2. Storm door
    3. Air locks
    4. None of above
G. Windows
    1. Weatherstripping
    2. Storm windows
    3. Materials/composition

Reference 1, pp. 5-34, 5-37

        a. Frame
        b. Single or double pane glazing
    4. Window types
        a. Single hung
        b. Double hung
        c. Fixed
        d. Horizontal sliding
        e. Jalousie
        f. Casement

Reference 1, pg. 5-35

H. Infiltration air - how many CFM?
I. Ventilation air - how much?
J. Auxiliary heating combustion air requirements
    1. Natural gas
    2. Oil
    3. Wood
K. Insulation
    1. Type - K- or C-factors

2. Amount - R-factor (thermal resistance)

L. Duct losses
   1. Above ceiling
   2. Furred down
   3. Below floor
   4. Embedded in slab

Reference 3, pp. 1-4, 1-7
Reference 5, Section 6

Use a printed hand-out of these procedures - example calculations.

Unit 3. Calculation Procedure

A. Worksheet method
   1. Select outside design temperature, T_o, from available tables
   2. Select inside design temperature, T_i
   3. Design temperature difference for heating $(T_i - T_o)$
   4. Calculate net area, A, of walls, doors, windows, floors and ceilings for each different type construction for each living space exposed to unconditioned space (use appropriate T_o for partitions exposed to unconditioned space)
   5. Calculate U-factor for each area in step 4
   6. Calculate heat transmission loss rate through each surface for each living space $Q(\text{Btu/hr}) = UA(T_i - T_o)$
   7. Total the transmission losses
   8. Calculate the infiltration losses (include ventilation requirements if applicable)
   9. Add infiltration losses to transmission losses for total structural losses
   10. Subtract internal heat gains, where appropriate (usually insignificant, therefore, ignored) for total building heat loss rate

    11. Convert heat loss rate (Btu/hr) to Btu/Degree Day

Example of completed J-1 form

- B. NESCA method
  - 1. Use of Manual J
    - a. Procedure
    - b. Heat transfer multipliers - examples
  - 2. Form J-1 - demonstrate

Select one and show completed sample calculations.

- C. Manufacturer's worksheets
  - 1. Fast method
  - 2. Accuracy is questionable
- D. Utility company worksheets
  - 1. Fast method
  - 2. Reliability varies with form and structure

Reference 1, Module 5

Unit 4. Thermal Analysis - Space Heating

- A. Daily load (Btu/DD X DD for day) - calculate
- B. Monthly load (Btu/DD X DD for each month) - determine
- C. Annual load (Btu-DD X DD for year) - determine

STUDENT ACTIVITY

Laboratory:

Exercise

Given a building blueprint or sketch, the student should identify the factors (walls, windows, doors, etc.) that will allow heat loss from the building and complete a short form load calculation.

Lab Exercise I
Laboratory Materials and Tools:

Building blueprint or sketch, hand-held calculator, Table of K-, C- and R-factors for building materials, NESCA form J-1.

Laboratory Procedure:

1. Construct a worksheet for load analysis.
2. Calculate the transmission heat loss of the building.
3. Using NESCA form J-1 and same blueprint or sketch, calculate the transmission heat loss of the building.
4. Compare the results of the two calculation methods.

Lab Exercise II
Laboratory Materials and Tools: Hand-held calculator and results form Lab Exercise I.

Laboratory Procedure:

1. Analyze the thermal loads:
    a. Daily load (Btu/day)
    b. Monthly load (Btu/month)
    c. Annual load (Btu/year).
2. Identify areas that could be made more energy efficient at reasonable cost.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Calculate and analyze the thermal load - cooling - for a given building and application.

(2) Identify the high load areas, i.e., walls, windows, doors, spaces, etc.

(3) Compare and analyze how building configuration affects a difference between the heating load and cooling load.

(4) Analyze the thermal gains of the building for energy conservation recommendations.

RATIONALE:

The system sizing process continues, but the application (cooling) is different. The methodology, used in designing the total system, is analyzed in a sequential manner.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings, Design of Systems, U.S. Department of Commerce, 1977.

(2) Handbook of Fundamentals, ASHRAE, N.Y., 1974.

(3) Carrier Corp., Handbook of System Design, McGraw-Hill Book Co., N.Y., 1965.

(4) Kreith, Frank, Principles of Heat Transfer, Intext Publishers, N.Y., 1973.

(5) Load Calculation, Manual J., NESCA, Arlington, Virginia, 1975.

(6) Löf, George O.G., Design and Construction of a Residential Solar Heating and Cooling System, NSF GI-40457, NTIS, Springfield, Virginia, 1974, NSF-RA-N-74-104.

(7) Pickering, Ellis E., Residential Hot Water Solar Energy Storage Subsystems, NSF C-905, NTIS, Springfield, Virginia, 1976, NSF RA-N-75-095.

UNIT TITLES:

(1) Calculation Procedure

(2) Cooling Load Calculations

(3) Short Form Methods

(4) Thermal Analysis - Space Cooling

VOCABULARY:

- Familiarity Gain
- Design Temperatures
- Design Temperature Difference
- Heat Transfer Multipliers
- Storm Doors
- Storm Windows
- Thermal Pane Windows
- Single Pane Windows
- Infiltration Air
- Ventilation Air
- Structural Gains
- Internal Gain
- Duct Loss
- Blueprint
- Sketch
- NESCA
- Short Forms
- Daily Load
- Monthly Load
- Annual Load
- Latent Heat

NOTE TO INSTRUCTOR:

Use the procedures discussed (demonstrated in Units 1 and 2 of the previous Module (Thermal Load Analysis - Space Heating) to survey the building and determine the factors that influence heat gain to the space.

CAUTION:

Be certain that the major factors that are different [Namely, (1) Degree Days Cooling - July and annual, (2) Design Temperatures, (3) Effective Temperature Difference, (4) Duct Gains, (5) Latent Heat Gain] are clearly defined. Use examples to demonstrate the differences.

Reference 3, pp. 1-4, 1-7
Reference 5, Section 10
Show example calculations

Unit 1. Calculation Procedure

A. Worksheet method

1. Select outside design temperature, T_o from available tables
2. Select inside design temperature, T_i
3. Design temperature difference for cooling ($T_o - T_i$)
4. Calculate net area, A, of walls, doors, windows, floors, and ceilings for each different type construction for each living space exposed to unconditioned space (use appropriate T_o for partitions exposed to unconditioned space)
5. Calculate U-factor for each area in step 4
6. Calculate heat transmission gain rate through each surface for each living space $Q(\text{Btu/hr}) = UA(T_o - T_i)$

   NOTE: Be sure to use effective temperature difference in appropriate areas

7. Total the transmission gain

8. Calculate solar gain from windows, glass, doors, and walls
9. Calculate infiltration gain (include ventilation requirements if applicable)
10. Add sums of steps 8 and 9 to sum of transmission gains (step 7)
11. Calculate gain from people, kitchen equipment, appliances and lighting
12. Add to total structural gain (step 10)
13. Calculate duct gain and add a sum from step 12
14. Multiply sum from step 13 times 1.3 to allow for latent heat (add to this figure any unusual latent heat gains). This figure represents the Total Cooling Load

B. Proof your work

Unit 2. Cooling Load Calculations - NESCA Method

Use sample cooling load calculation.

A. Use of Manual J
  1. Procedure
  2. Heat transfer multipliers - use example
  3. Correction factors - explain

B. Form J-1 - demonstrate

Unit 3. Short Form Methods

Pass around sample calculations to the students.

A. Manufacturer's worksheets
  1. Fast method
  2. Questionable accuracy

B. Utility company worksheets
  1. Fast method
  2. Reliability varies

Unit 4. Thermal Analysis - Space Cooling

Reference 1, Module 5

A. Daily load (Btu/DD X DD for day) - determine

B. Monthly load (Btu/DD X DD for each month) - calculate

C. Annual load (Btu/DD X cooling DD for year) - determine

STUDENT ACTIVITY

Exercise I

Assignment:

Given a building blueprint or sketch the student should identify factors (walls, ceilings, windows, doors, etc.) that allow heat gain to the building and complete a short form cooling load calculation.

Laboratory Materials and Tools:

Building blueprint or sketch, hand-held calculator, Table of K-, C- and R-factors for building materials, NESCA form J-1, and NESCA Manual J.

Laboratory Procedure:

1. Construct a worksheet for load analysis.
2. Calculate the transmission and solar heat gain of the building.
3. Calculate the internal heat gain of the building, and add to transmission and solar gain.
4. Calculate the latent heat gain and add to sum of step 3 for total heat gain.
5. Complete NESCA for J-1, for same building, to obtain total heat gain.
6. Compare the results from step 4 and step 5 of procedures.

Exercise II

Laboratory Materials and Tools:

Hand-held calculator and results from Exercise I.

Laboratory Procedure:

1. Calculate the monthly and annual thermal load.
2. Analyze the thermal loads for high load areas and time.
3. Identify areas that could be made more energy efficient at reasonable cost.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Determine service water usage for varying family sizes.

(2) Obtain and average tap water temperature for the applicable community.

(3) Calculate service hot water thermal load.

(4) Calculate storage capacity required.

(5) Analyze thermal load and solar fraction.

(6) Calculate auxiliary requirements.

RATIONALE:

The elements and data required for designing and/or sizing the components of the solar system are examined in depth. This is the third, and last residential system load to be considered for design/sizing purposes.

REFERENCES:

(1) Duffie, John A. and William A. Beckman, Solar Energy Thermal Processes, John Wiley and Sons, N.Y., 1974.

(2) Colorado State University, Solar Heating and Cooling of Residential Buildings: Design of Systems, U.S. Department of Commerce, 1977.

(3) SMACNA, Fundamentals of Solar Heating, U.S. Department of Energy, EG-77-C-01-4038, 1978.

(4) Jordan, Richard C. and Y. H. Lin Benjamin, Editors, Applications of Solar Energy for Heating and Cooling Buildings, ASHRAE, N.Y., 1977.

(5) Pickering, Ellis E., Residential Hot Water Solar Energy Storage Subsystems, NTIS, U.S. Department of Commerce, Springfield, Virginia, NSF C-905, NSF RA-N-75-095, 1976.

UNIT TITLES:

(1) Water Use

(2) Calculation Procedure

(3) Thermal Load Analysis

VOCABULARY:

Tap Water

Preheat Temperature

Service Water Load

Solar Fraction

Auxiliary Requirements

Reference 4, Chapter 9
Reference 2, Module 19

Unit 1. Water Use - Determine
- A. Survey method - (requires metering)
  1. Dishwashing
  2. House cleaning
  3. Number of occupants
  4. Bathing
- B. Estimate method
  1. Number of occupants
  2. 20 gal/occupant/day

Reference 1, Chapter 4
Reference 2, Module 19
Reference 3, Chapter 8

Construct an organized, table form for these calculations.

Demonstrate example calculations (chalkboard).

Unit 2. Calculation Procedure
- A. Determine usage in gallons per day
- B. Determine desired storage temperature or preheat temperature, T_o
- C. Determine storage capacity
- D. Determine incoming (tap) water temperature, annual average and monthly average - (local water supply)
- E. Calculate service water load , Btu/Day = Gal/Day X 8.33 X $(T_o - T_1)$, $(Q = MC\Delta t)$

Reference 2
Use sample calculations (chalkboard).

Unit 3. Thermal Load Analysis
- A. Solar fraction of January load - calculate
- B. Solar fraction of July load - calculate
- C. Auxiliary requirements - determine
  1. Btu/day
  2. Btu/month
     a. Best solar month
     b. Worst solar month

NOTE TO INSTRUCTOR:

There are many other more detailed methods, i.e., an annual load, annual solar fraction, etc. Suggest, if time allows, another method be demonstrated.

STUDENT ACTIVITY

Assignment:

Exercise

The student should contact the local water company (or other available sources) and record the tap water temperatures for the months of January, April, July, and October.

Laboratory Materials and Tools:

Data for tap water temperatures for above months, hand-held calculator and water use data for a family of four.

Laboratory Procedure:

1. Determine storage or preheat temperature.
2. Calculate service water thermal load.
3. Determine the required storage capacity.
4. Calculate solar fraction for:
    a. January load
    b. April load
    c. July load
    d. October load.
5. Calculate auxiliary requirements (Btu/day and Btu/month) for:
    a. Best solar month
    b. Worst solar month.

MODULE: SIZING AND SELECTION OF COLLECTOR ARRAY-MANUAL METHOD

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Use a short form method to calculate the area of the collector array air and liquid systems.

(2) Calculate the size of the collector array using the manual f-chart method.

(3) Discuss collector flow patterns for air and liquid collectors.

RATIONALE:

The necessary preliminary information, considerations, and thermal calculation skills have been presented, and hopefully mastered. It is now time to begin the process of sizing the components required for the system. The first of these to be considered is the collector array. Some methods, frequently used, require the sizing and type selection of the collector array as the first step of the procedure.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings: Design of Systems, U.S. Department of Commerce, 1977.

(2) Solar Training Manual, Phase I, Lennox Industries Educational Department, Dallas, Texas, 1979.

(3) Applications Engineering Manual, Solaron Corporation, Denver, Colorado, 1978.

(4) Intermediate Minimum Property Standards Supplement - 4930.2, 1978.

(5) Solar Energy for Buildings Handbook, D.O.E., ORO-5362-T1.

UNIT TITLES:

(1) System Decisions

(2) Short Form Methods

(3) Short Form Calculations - Liquid System

(4) Short Form Calculations - Air System

(5) Manual F-Chart Calculations

VOCABULARY:

- Design Temperature Difference
- SA/L Method
- SCF (Solar Conversion Factor)
- X and Y Axis
- Direct Return
- Stagnation Temperature
- LC Factor
- Effective Absorber Area
- Manual F-Chart Method
- F-Chart Parameters
- Reverse Return
- Thermal Expansion

MODULE: SIZING AND SELECTION OF COLLECTOR ARRAY-MANUAL METHOD

Reference 1, Module 4
Reference 4, Chapter 11,12, & 13
Reference 5, pg. 115

Unit 1. System Decisions

- A. What is the application?
  - 1. Domestic hot water
  - 2. Space heating only
  - 3. Space heating and cooling
- B. Collectors - liquid or air systems?
  - 1. Advantages of each
  - 2. Disadvantages of each
  - 3. Typical flow patterns required
    - a. Liquid collectors
    - b. Air collectors
- C. Storage
  - 1. Air system options - describe
    - a. Advantages
    - b. Disadvantages
  - 2. Liquid system options - describe
    - a. Advantages
    - b. Disadvantages
- D. Heat transport system
  - 1. Air system options - what are they?
    - a. Advantages
    - b. Disadvantages
  - 2. Liquid system options - what are the choices?
    - a. Advantages
    - b. Disadvantages
- E. Basic control options - discuss
- F. Economic factors - explain influence on decision

Reference 2, pp. 6-1, 6-2
Reference 1, Module 4

Unit 2. Short Form Methods

- A. Purpose of short form calculations
  - 1. Quick
  - 2. Needed for cost estimate
  - 3. Used in sales
- B. Discuss short form variables
  - 1. Rules of thumb
  - 2. Manufactures output/collector
  - 3. Load/collector factor - LC
  - 4. Solar fraction
  - 5. Tilt angle and orientation
  - 6. Usually no distinction

between air and liquid

C. ASHRAE method

Make and pass to students a printed hand-out of the ASHRAE method.

STUDENT ACTIVITY

Reference 1, Module 4

Assignment:

Given the procedures and flow charts for the Huck-Winn method and the Balcomb-Hedstrom method, January space heating load, latitude, orientation, tilt angle of latitude +10°, solar fraction of .75 and collector performance curves, the student should:

1. Select the size of the collector array using the Huck-Winn method.
2. Select the size of the collector array using the Balcomb-Hedstrom method.
3. Compare and analyze the results of the two methods.
4. Make system decision, air or liquid, based upon your conclusions. State your rationale for the decision.

Reference 2, Equipment Selection Section, pg. 3

Unit 3. Short Form Calculation - Liquid System Array

NOTE: Assume solar fraction of 50 percent and Dallas, Texas as the city.

INSTRUCTOR ACTIVITY
Use Chalkboard, printed hand-out or overhead transparency of procedures.

A. Use design heat loss from on Design Procedure Parameters
B. Determine design temperature difference for Dallas, Texas
C. $\frac{\text{Btu/hr loss rate}}{\text{Design T.D.}} \times 24 =$ Btu/Degree Day
D. Solar fraction = 50 percent
E. Approximate total collector area is:
$$\frac{\text{Btu/Degree Day}}{\text{LC factor (table) 75 percent}}$$
F. Determine effective absorber area for collector under consideration

G. Number of collectors required:
$$\frac{\text{area of collector array}}{\text{effective absorber area}}$$
H. (Round number of collectors required upward to nearest single number)
I. Number of collectors X effective absorber area equals total effective absorber size - ft^2
J. Number of collectors X area required for mounting and connection of collectors equals gross collector area (ft^2) required

INSTRUCTOR ACTIVITY

Demonstrate the utility of the short form calculation.

Demonstration:

Demonstrate the use of the short form for sizing the collectors - liquid system.

Reference 3, Section 800

Use chalkboard, printed hand-out or overhead transparency of procedures.

Unit 4. Short Form Calculation - Air System Array
A. Use design heat loss from exercise in module on Design Parameter Procedures
B. Assume collector tilt angle of 35^{o}
C. Assume solar fraction (fuel savings) of 50 percent and Dallas, Texas as the city
D. Heat loss (Btu/hr) ÷ design temperature difference = Btu/hr/^{o}F for the building
E. Btu/hr/^{o}F (building) ÷ solar conversion factor (S.C.F.) equals number of collector panels required
F. Collector area equals number of panels X effective absorber area/panel
G. Compare area required in 1-J above with 2-F above (comparison of liquid system to air system - collectors only)

Reference 3, pg. 800.15

MODULE: SIZING AND SELECTION OF COLLECTOR ARRAY-MANUAL METHOD

INSTRUCTOR ACTIVITY	Demonstration: Demonstrate the use of the short form in sizing the collector array - air system.
Reference 4, Appendix A Call in assignment made in previous module: Design Procedure Parameters.	Unit 5. Manual F-Chart Calculations A. Review f-chart calculations B. Demonstrate use of f-chart curves for determining solar fraction for 2 or more collector array sizes
STUDENT ACTIVITY	Laboratory:
Exercise Laboratory Materials and Tools:	Given a residential building drawing (sketch), plot plan and its thermal losses (Btu/hr) for the month of January, radiation tables, collector performance curve, collector array size (ft^2), collector parameters for x and y axis, an f-chart, and the interactive curves for Washington, D.C. (Reference 1, fig. 7-34).
Laboratory Procedure:	1. Decide which collector system (air or liquid) would be better for the application. Check the building drawing (sketch) and the plot plan. 2. The student should determine the solar fraction using the f-chart. 3. The student should compare solar fraction for collector array of 250 ft^2, 500 ft^2 for the building load in Washington, D.C. 4. Decide which flow pattern would be most appropriate for the system chosen.

MODULE: SIZING AND SELECTION OF THE STORAGE SYSTEM

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Select the appropriate storage vessel materials.

(2) Calculate the storage capacity that matches the load requirements and collector array area for:
   a. Liquid storage
   b. Rock storage.

(3) Calculate the weight of the:
   a. Liquid storage
   b. Rock storage.

RATIONALE:

Collection of the solar heat is only the first step in the process. Heat will be needed when the sun is not shining (at night). For space heating applications this is the time of greatest demand. Also, heat storage is needed for those times when collection is not possible. The match between collection system and storage system is essential. Too much storage capacity is as detrimental to the system as too little storage. Correct selection of the storage medium and storage capacity is essential.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings: Design of Systems, U.S. Department of Commerce, 1977.

(2) Colorado State University, Solar Heating and Cooling of Residential Buildings: Sizing, Installation and Operation of Systems, U.S. Department of Commerce, 1977.

(3) Applications Engineering Manual, Solaron Corporation, Denver, Colorado, 1978.

UNIT TITLES:

(1) Liquid System Storage

(2) Air System Storage

VOCABULARY:

Capacity
Air Stratification
Density
Horizontal Flow (Pebble Bed)
Liquid Stratification
Baffles
Phase Change Compounds

Reference 2, pp. 6-12
Reference 1, pp. 7-4

Unit 1. Liquid System Storage

A. Briefly discuss storgae container materials

B. Describe storage characteristics and parameters

Reference 1, pp. 7-8

C. Economics indicate capacity range of 1.25 to 2 gal./1 ft^2 of collector array

D. Discuss the effects of oversizing the storage capacity

E. Discuss the effects of undersizing the storage capacity

Reference 2, pp. 6-10

Use line drawing, slides or overhead transparency for illustration.

F. Describe appropriate installation methods and techniques
   1. Within the structure
   2. Outside the structure
      a. Above ground level
      b. Below ground level
   3. Insulation
   4. Connections and fittings

Reference 2, pg. 6-13 thru 6-16
Reference 3, Sections 400 and 800

Use illustrated graphics of rock storage bed for Unit 2-B, D, E. (Cross-sectional views would be effective here)

Unit 2. Air System Storage

A. Briefly discuss storage container materials and construction methods

B. Describe storage medium characteristics and parameters
   1. Pebbles - size
   2. Phase change compounds
   3. Density (weight/ft^3 of pebbles
      a. Example - 1" dia.
      b. Example - 3/4" dia.

C. Discuss storage capacity

D. Define and give examples of air stratification; how it is used in pebble bed storage

E. Pebble bed depth and pressure drop as a function of air velocity and pebble size

F. Describe problems encountered with horizontal flow pebble bed. How are they treated?

G. Explain the effects of undersizing and oversizing the pebble bed

STUDENT ACTIVITY

Laboratory:

Exercise

Given the area of a collector array, the student should calculate:

Laboratory Procedures:

1. The gallons of water required for a liquid system.
2. The weight of the water required.
3. The diameter of the vessel if the height could not exceed 6 feet.
4. The cubic feet of pebbles required for an air system.
5. The weight (in tons) of the pebbles.
6. The length of the pebble bed with a pebble depth of 5 feet and width of 6 feet maximum.

MODULE: SIZING AND SELECTION OF THE SUBSYSTEM COMPONENTS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Determine the type of piping material that will assure compatibility.

(2) Calculate the pipe sizes needed for the transport system, (liquid system).

(3) Select the appropriate pump.

(4) Calculate the air duct sizes required (air system).

(5) Select the fan/blower appropriate for the application.

(6) Size and select appropriate heat exchangers.

RATIONALE:

Once the collector array is selected and the storage medium and size is determined, means of transporting the heat from collectors to storage and storage to portable water tank or space must be selected and sized. This module explores the means of transport and the heat movers of the system.

REFERENCES:

(1) Colorado State University, *Solar Heating and Cooling of Residential Buildings: Design of Systems*, U.S. Department of Commerce, 1977.

(2) *Solar Training Manual, Phase* I, Lennox Industries Educational Department, Dallas, Texas, 1979.

(3) *Applications Engineering Manual*, Solaron Corporation, Denver, Colorado, 1978.

(4) *Air Distribution System Selection and Design, Manual* D, NESCA, Arlington, Virginia, 1979.

(5) Howell, Yvonne and Justin A. Bereny, *Engineers Guide to Solar Energy*, Solar Energy Information Service, San Mateo, California, 1979.

UNIT TITLES:

(1) Hydronic System Components

(2) Air Distribution System Components

(3) Heat Exchangers and Heat Transfer Fluids

(4) Selection and Sizing Criteria - Service Water Air System

VOCABULARY:

Liquid Flow Chart
Friction Loss
Feet of Head
Pump Curves
Plenum
External Static Pressure
Main Trunk (Air)
Branch Trunk (Air)
Return Trunk (Air)
Heat Transfer Fluid
Ethylene Glycol
Log Mean Temperature Difference
Heat Transfer Coefficient
Darcy-Weisback Equation
Reynolds' Number
Velocity
Viscosity
Bare Tube
Finned Tube
Spiral Tube
Single Wall Exchanger
Double Wall Exchanger
Approach Temperature
Propylene Glycol
Silicone Fluids

MODULE: SIZING AND SELECTION OF THE SUBSYSTEM COMPONENTS

Reference: Collectors and **Storage** Course	Unit 1. Hydronic System Components (Review Module: Hydronic System Components From the Collectors and Storage Course. Emphasize The Following:)
System piping schematic and pump curves (printed handout and overhead trnsparency would help in clarification)	A. Pipe sizing - use liquid flow chart B. Friction loss of piping and fittings in ft. of head C. Friction loss of valves and flow control devices in
Reference 2, data section, pp. 22-25 Reference 1, pp. 16-11 to 16-15	D. Pump sizing - use the pump D. Pump sizing - use the pump curves shown in Reference 3
Reference: Collectors and Storage Course	Unit 2. Air Distribution System Components. (Review Module: Air Distribution Components From the Collectors and Storage Course. Emphasize the Following:)
Reference 3, pp. 800.18 to 800.20 Reference 4, Chapters 5 & 6 Use printed handout and overhead transparency of air duct system.	A. **Duct** sizing 1. Friction loss 2. Velocity requirements B. Duct and plenum fittings 1. Friction loss 2. Velocity requirements C. Fan/blower selection 1. CFM capacity 2. External static pressure rating D. Supply registers - sizing E. Return registers - sizing F. Main trunk velocity - noise level G. Branch trunk velocity - noise level H. Return trunk velocity - noise level
Reference: Collectors and Storage Course	Unit 3. Heat Exchangers and Heat Transfer Fluids (Review Collectors and Storage Course, Module: Heat Transfer Fluids-Heat Exchangers. Give Emphasis To:)
Module: Heat Transfer Fluids	A. Heat transfer fluids 1. Characteristics and thermal properties of: a. Air b. Water c. Ethylene glycol/ water d. Propylene glycol/

Module: Heat Exchangers
Reference 1, Module 16

Overhead transparency or slides, showing cross-sectional view of heat exchangers (different types).

Reference 1, pp. 7-5, 7-8, Module 16
Reference 2, Equipment Section, pp. 19-23
Reference 5, pg. 242

Show overhead transparency or hand out copy of Reference 3 Equipment Section, pp. 20 & 21.

water
- e. Mineral oils
- f. Silicone fluids

2. Fluid transfer considerations
   - a. Darcy - Weisback equation
   - b. Reynolds' number
     - 1) Velocity
     - 2) Viscosity
     - 3) Pressure drop through circulating equipment and heat exchanger

B. Heat Exchangers
1. Review types of heat exchangers
2. Review transfer materials and the coefficient of heat transfer for:
   - a. Bare tube
   - b. Finned tube
   - c. Spiral tube
3. Describe flow patterns and baffles - their effect on efficiency
4. Single wall and double wall requirements
5. Selection and sizing criteria - liquid system
   - a. Define approach temperature difference - give example of approach parameters ($10^{\circ}\Delta t$, $15^{\circ}\Delta t$, etc.)
   - b. Define log mean temperature difference - give example
   - c. Discuss changes in heat exchanger efficiency as a function of flow rate, collector fluid temperature and storage temperature
   - d. Calculate log mean temperature dif-

ference for a given application

e. Calculate heat exchanger efficiency for the application above

Reference 3, pp. 800.8 - 800.10, 800.18 - 800.20

Reference 1, pp. 16-15 to 16-30

Unit 4. Selection and Sizing Criteria - Service Water Air System

A. Determine available external static pressure for supply air from fan/blower charts
B. Select C.F.M. required for the system
C. Determine air temperature in the duct
D. Determine water flow rate through the coils and the heat transfer coefficient between the air and coil
E. From manufacturer's specification sheet, select the appropriate heat exchanger

STUDENT ACTIVITY

Exercise I

Assignment:

Given the thermal load of the building, collector array size, storage capacity, design temperatures, piping charts and graphs, pump performance curves, and heat exchanger specification sheets, the student should:

1. Calculate the pipe sizes needed.
2. Select the appropriate pump.
3. Select the appropriate heat exchanger(s) and the flow pattern required.

STUDENT ACTIVITY

Exercise II

Assignment:

Given the thermal load of the building and service hot water, collector array size, storage capacity, design temperatures, air flow charts, duct tables, fan/blower performance curves or tables, and heat exchanger specification sheets, the student should:

1. Calculate the duct size required.
2. Select the appropriate fan/blower.
3. Select the appropriate heat exchanger for the service hot water.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Select appropriate and required protection devices.

(2) Explain the purpose/function of controls and sensors.

(3) Relate the controls to the controlled devices.

(4) Discuss the purpose of system interlocks.

(5) Describe the sequence of operation of a typical air and liquid system.

RATIONALE:

Solar systems must not be allowed to "run free". Overshooting desired temperature is an undersirable condition. Long temperature lag time is also a detrimental human comfort. System protection is crucial since the cost of the system represents a sizeable investment. Control and protection of the processes are critical to cultivating a satisfied owner/customer.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings: Design of Systems, U.S. Department of Commerce, 1977.

(2) Applications Engineering Manual, Solaron Corporation, Denver, Colorado, 1978.

(3) Haines, Roger W., Control Systems for Heating, Ventilation and Air Conditioning, Van Nostrand Reinhold, Environmental Engineering Series, N.Y., 1971.

UNIT TITLES:

(1) Sizing and Selecting System Protection Devices

(2) Selecting the Control System

VOCABULARY:

Expansion Tanks
Air Eliminators
Vacuum Breakers
Anti-Syphon Devices
Filters
Flow Switches
Pressure Regulators
Pressure-Relief Valves
Check Valves
Dampers
Control Logic
Controllers
Controlled Devices
Actuator
Zone Valves
Thermostats
Pressurestats
Differential Controller
Sensors
System Interlock

Reference: Collectors and Storage Course, Module: Hydronic System Components
Reference 1, Chapter 16

Unit 1. Sizing and Selecting System Protection Devices (Review Collectors and Storage Course, Module: Hydronic System Components. Emphasize:)

A. Expansion tanks
B. Air eliminators
C. Vacuum breakers
D. Anti-syphon devices
E. Filters
F. Flow switches
G. Pressure regulators
H. Pressure-relief valves
I. Check valves
J. Dampers
K. Installation methods and techniques

INSTRUCTOR ACTIVITY

Demonstration:

Using a solar trainer, the solar system in your lab or a field trip, locate and describe the function of each of the above protection devices. If practical, activate the system and demonstrate the action of as many of these devices as is possible. Also, point out any installation techniques or problems that might be unique to any device.

Exercise

Given a solar system (liquid), possibly the one demonstrated above, have the student select the appropriate pressure regulator, pressure-relief valve, and expansion tank.

Reference: Collectors and Storage Course, **Module:** Controls and Controlled Devices

Reference 3, Chapter 1

Reference 1, Chapter 15

Unit 2. Selecting the Control System (Review Collectors and Storage Course, Module: Controls and Controlled Devices. Give Emphasis To:)

A. Control theory
B. Control logic
C. Examples of controllers
D. Examples of controlled devices (actuators)
E. Selection of controls and controlled devices
   1. Occupant controls
      a. Thermostats
      b. Zone valves and dampers
   2. Automatic controls
      a. Describe the function of:

        1) Collector controls
        2) Differential controllers
        3) Freeze protection-aquastat
        4) Thermostats
        5) Pressurestats
3. Discuss the sensors used to actuate each of the above automatic controls
    a. Sensor types
    b. Sensor location

INSTRUCTOR ACTIVITY

Demonstration:

Select an operational solar system (trainer or the one in your laboratory), locate and identify each of the control sensors, actuators, and the controlled device. Also, explain the need for and function of the control panel.

F. Explain the purpose of "System interlocks"

Printed hand-out, line drawings on chalkboard or overhead transparency of Reference 1, Figures 15-1 and 15-2. Reference 3, pp. 500.6 - 500.8

G. Control subsystem-air - using schematic diagrams, describe the sequence of operation for typical solar air heating system

Printed hand-out line drawings on chalkboard or overhead transparency of Reference 1, Figures 15-5 and 15-6.

H. Control subsystem-liquid - using schematic diagrams, describe the sequence of operation for a typical solar liquid heating system

STUDENT ACTIVITY

Laboratory:

Laboratory Materials and Tools:

An operational solr trainer or solar system, hand tools, and multimeter.

Laboratory Procedure:

The student should dry run the control system through the full sequence of modes by changing the thermostat, aquastat, and pressure stat set points.

NOTE: If the system is equipped with a flow switch or no flow alarm, it may have to be bypassed to obtain all sequences.

The student should make note of any malfunctions or deviation from the design sequence.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Make specific energy conservation recommendations for the structure under consideration.

(2) Determine building, site, or location limitations:
   a. That would prohibit solarizaton of the building.
   b. Indicate partial solarization would be the better decision.

(3) Complete a Life Cycle Cost Analysis of the retrofitted solar system.

RATIONALE:

Solar installations for new construction are usually considered during the building design process. Preliminary considerations and potential problems are hopefully resolved before the installation begins. In retrofitting systems to existing structures, additional problems (opportunities) are encountered that may not be so easily resolved. Solutions to these obstacles are not always easy and in fact, cannot be resolved, requiring alternative decisions. It is the intent of this module to explore these "opportunities" and offer potential solutions/resolutions.

REFERENCES:

(1) Colorado State University, Solar Heating and Cooling of Residential Buildings - Sizing Installation and Operation of Systems, U.S. Department of Commerce, 1977.

(2) Anderson, Bruce, Solar Energy - Fundamentals in Building Design, McGraw-Hill Book Co., N.Y., 1977.

(3) Intermediate Minimum Property Standards Supplement 4930.2, U.S. Department of Housing and Urban Development, 1977.

(4) Solar Training Manual, Phase I, Lennox Industries Educational Department, Dallas, Texas, 1979.

UNIT TITLES:

(1) General Considerations

(2) Specific Considerations

(3) Equipment Considerations

(4) Retrofit Decisions

VOCABULARY:

Retrofit
Building Permits
Property Covenants
Orientation
Air Distribution System
Life Cycle Cost Analysis
Energy Conservation
Zoning Regulations
Siting
On-Site Assembly
Hydronic System
Solar Assisted Heat Pump

Reference: Energy Conservation and Passive Design Course

Unit 1. General considerations
- A. Energy Conservation measures - discuss methods of conserving energy in existing buildings
    - 1. Insulation
    - 2. Weatherstripping
    - 3. Caulking
    - 4. Attic ventilation
        - a. Summer
        - b. Winter
    - 5. Landscaping - trees
        - a. Summer
        - b. Winter
    - 6. Awnings
        - a. Summer
        - b. Winter
    - 7. Thermal glazing
        - a. Double pane windows
        - b. Storm windows
        - c. Storm doors
- B. Consider present building structure, location, and limitations
    - 1. Siting and orientation of building
    - 2. Shading - landscape surrounding buildings and other sun obstructions
    - 3. Present glazing
    - 4. Roof shape (type) and structural strength
    - 5. Energy conservation measures required
    - 6. What changes would be required?
        - a. Add a room or equipment space
        - b. Tear out a wall, doors, windows, etc. Storage vessel may not pass through present structural entries (storage vessel may have to be built in sections and assembled inside the building)

Line drawing or overhead transparency of roof type and pitch angles.

Reference 3, Chapter 3

Printed handout of local zoning limitations.

Unit 2. Specific Considerations

- A. Discuss local limitations
  - 1. Zoning regulations
  - 2. Fees and permits
  - 3. Neighborhood - aesthetics would it blend with surroundings
  - 4. High visibility of solar collectors
- B. What are the legalities that might be encountered?
  - 1. Sun rights
  - 2. Property covenants
- C. Cost of making the building and/or site solar acceptable is chargeable to the cost of solar installations
  - 1. Landscaping
  - 2. Grading
  - 3. Building changes (even though only temporary)

Reference 3, Chapter 4

- D. Discuss fire safety and fire protection that might be required

Reference 1, Module 18
Reference 4, Installation Section, pg. 52

- E. Discuss adaptability to present building equipment
  - 1. Electrical needs
  - 2. Plumbing needs
  - 3. Air distribution system
  - 4. Modification of control systems
  - 5. Where would the solar equipment be located
  - 6. Are the materials joining the systems together compatible
  - 7. Cost of any modifications or changes here must be added to the cost of the solar system

STUDENT ACTIVITY

Laboratory:

NOTE TO INSTRUCTOR:

Try to arrange a field trip for the purpose of examining a structure that might lend itself to solar system retrofit. Homes of some of the students would be likely candidates. If this activity is not possible, provide the students with a residential building blueprint or sketch (of 10-15 year vintage so that energy conservation measures are probably in order).

Have the students:

1. Make note of the applicable energy conservation measures, discussed in Unit 1.
2. Make specific recommendations for these energy conservation measures.
3. Note any building structure or location limitations that might impede the installation of a solar system.
4. Decide if partial solarization would be recommended.
5. Note adaptability to present building equipment problems that might be encountered (Unit 2-D).

Reference 1, Module 18
Reference 2, pp. 120-123
Reference 4, Installation Section, pg. 51
Illustrated graphics, slide, overhead transparency and printed handout would clarify some of these topics.

Unit 3. Equipment Considerations

- A. Collector Array
  1. Describe possible array arrangements
  2. Discuss roof pitch angle - existing pitch
     - a. Advantages
     - b. Disadvantages
     - c. Will it need to be changed?
     - d. Would it be cost effective?
  3. Describe retrofit collector mounting methods
     - a. Roof mounted
       - 1) Aesthetic problems
       - 2) Structural problems
     - b. Ground mounted
       - 1) Aesthetic problems
       - 2) Structural problems
     - c. Wall mounted
       - 1) Aesthetic problems
       - 2) Structural problems
       - 3) Efficiency degradation

Reference 1, Module 18
Reference 2, pg. 122
Reference 4, Installation Section, pg. 52

- B. Storage system
  - 1. Discuss unique storage
    - a. Tall water tanks
    - b. On-site assembly of pre-fabricated pebble bed boxes
  - 2. Discuss location of storage system
    - a. In the garage
    - b. Special room
    - c. Below ground
    - d. Advantages and disadvantages of above
- C. Circulation system
  - 1. Describe problems that might be encountered in:
    - a. Air distribution system
    - b. Hydronic system
  - 2. Discuss how the "marriage" of the systems might be accomplished
- D. Control system
  - 1. Describe the changes required
  - 2. Discuss alternative control methods

Reference 1, Module 15

Unit 4. Retrofit Decisions

- A. Using the information from the previous units in this module:
  - 1. Calculate conventional system operating costs
  - 2. Calculate life cycle cost of solar system retrofit
- B. How much solar system?
  - 1. **D.H.W.** only?
  - 2. Space heating only?
  - 3. Combined D.H.W. and space heating?
  - 4. Solar cooling?
  - 5. Solar assisted heat pump?

STUDENT ACTIVITY

Exercise

Laboratory:

Using the information and decisions from Unit 2 exercise, and assuming a solar system will be installed, the student should:

1. Decide how solarization will be added to the residence.
2. Size and select the system and subsystem components required.
3. Analyze the life cycle cost of the retrofitted system (add the cost of structural changes required to the solar equipment and installation cost).

MODULE: EQUIPMENT AND COMPONENT SELECTION AND SPECIFICATIONS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Interpret technical sketches.

(2) Locate manufacturers of specific equipment/item from catalogs or other publications.

(3) Set up and maintain indexes with cross references.

(4) Select equipment/items based upon parameters of choice.

(5) Write detailed equipment/item specification.

(6) Write a Bill of Materials.

RATIONALE:

Even though you may know what type, specific characteristics, application, and what size equipment is needed/indicated for the solar system, it is necessary that you know where to find it, how to select the best available choice, and how to write detailed specifications that will assure you get what you want. Return and re-order is very time consuming.

REFERENCES:

NOTE: The following refereces are to be used for example only.

(1) Solar Training Manual, Phase I, Lennox Industries Education Department, Dallas, Texas, 1979.

(2) Applications Engineering Manual, Solaron Corporation, Denver, Colorado, 1978.

(3) Solar Age Catalogue, Solar Vision Inc., Port Jervis, N.Y., 1977.

(4) Solar Engineering Master Catalogue, Solar Engineering Publishers, Inc., Dallas, Texas, 1979.

UNIT TITLES:

(1) Information Sources

(2) Equipment Selection

(3) Other Important Materials

VOCABULARY:

Specificity

Special Catalogs

Criterion/Criteria

Warranty Cards

Installation, Operation and Maintenance Manuals

Library of Congress Classification Numbers

Technical sketch

Cross-Index

Bill of Materials

Reference 3, pp. 128, 131, and 132

Unit 1. Information Sources

A. Use and interpretation of technical drawings and sketches
   1. Check for accuracy and specificity
   2. Symbols and interpretation (Use legend if available. All draftsmen and manufacturers do not use the same symbols for identification of devices)
   3. Look for pertinent application data
   4. Examine for unique characteristics

Any trade or technical publication(s) available.

Example: Solar Age
Solar Engineering Magazine

B. Technical publications, trade magazines, special catalogs, and manufacturers catalogs
   1. Maintain a current library of these sources
      a. Index by publication
      b. Cross-index by subject area, i.e., collectors, storage vessels, control systems, etc.
      c. File index cards on articles of specific interest, giving title, subject, publication, and library I.D. number (this may be your personal library or one available to students)
   2. Use the yellow pages of the telephone book
   3. Use retailers catalogs, such as parts supply houses, Sears and Roebuck, etc. Examples: Plumbing wholesalers, H.V.A.C. parts houses, Honeywell Tradeline catalog, Ranco catalog, steel and metals wholesalers or mills

Reference 4, pg. D-14
Reference 2, Section 200

C. Use of manufacturers' specification sheets
   1. Gives brief description of item
   2. May give physical characteristics
   3. Usually give performance date
      a. Graphs
      b. Charts
   4. May give typical applications
      a. Thermal applications
      b. Mechanical applications
      c. Electrical applications or requirements
   5. Almost always, give characteristics that make it unique or different from other manufacturer's product (if not given, ask about them)
   6. Maintain a file and cross-reference on these sources of information

INSTRUCTOR ACTIVITY

Demonstration/Laboratory:

Using a technical sketch of a domestic hot water solar system (using ethylene glycol in the collector loop), a solar catalog or SEM catalog, trade magazines and the telephone yellow pages, the instructor should:

1. Demonstrate interpretation of the technical sketch.
   a. Point out unique characteristics
   b. Ask the students to list pertinent data.
2. Demonstrate how SEM catalog is indexed and cross-indexed.
3. Select an item from the sketch; find manufacturer of the item through the use of catalogs, technical publications or trade magazines; and using the telephone yellow pages, locate a potential supplier.

4. Pass out copies of a manufacturer's specification sheet and demonstrate its use in making equipment decisions.

Unit 2. Equipment Selection

A. Establish parameters of choice
   1. Physical characteristics
   2. Performance criterion
   3. Flexibility/adaptability
   4. Availability - if not in stock, when?
   5. Substitution possibilities/alternatives, what else might work?
   6. Repair/replacement parts
   7. Calibration requirements - how difficult?
   8. What are the installation requirements?
   9. Difficulties that might be encountered in using the chosen equipment
   10. Warranty - full or limited? Limited - how?
   11. Check with others who have used the chosen equipment in the same or similar application

Reference procedure from your purchasing department, if applicable.

B. Writing equipment specifications
   1. Be specific and exact - give full description of item, i.e., 1/4" - 20 X 1 1/2" hexhead bolt, cadminum plated; copper tee 5/8" X 5/8" x 5/8" O.D. solder X solder. Learn trade jargon where applicable. Example: Copper tee described above could be listed as 5/8 x 5/8 x 5/8 x S copper tee. Tradesmen can usually spot novice by the way he/she talks
   2. Use standard items where possible

3. Include unique characteristics if the item must be bid
4. Ask potential suppliers for recommendations (telephone book, yellow pages is a good source)
5. Give the model number, if known
6. Construct a bill of materials
    a. Use table format
    b. Group material according to either types (elbows, tees, reducers, etc), or uses, (valves, pumps, fittings, etc.), or material composition (wood, steel, copper, glass, etc.). Regardless of the method chosen, be consistent. Consistency will reduce the chances for error.

INSTRUCTOR ACTIVITY

Demonstration/Laboratory:

1. Select a manufacturer's catalog, i.e., ITT, Bell and Gossett for pumps and heat exchangers; local plumbing or HVAC supply house for pipe, fittings, valves, etc.
2. Select an item from technical sketch (Unit 1, Demonstration/Laboratory) that could be found in the catalog of your choice.
3. Using the parameters of choice (Unit 2-A) select the appropriate equipment/item.
4. Write detailed specifications for the equipment/item.
5. Set up and write a short bill of materials.

NOTE TO INSTRUCTOR:

The above Demonstration/Laboratory could be a student exercise or an assignment.

Unit 3. Other Important Materials

- A. Installation, operation, and maintenance manuals
  - 1. Maintain a file
  - 2. Cross index by manufacturer and device
- B. Warranty cards and registration
  - 1. Filed according to owners name
  - 2. Be certain to fill out the information needed on the card, especially date of installation, job site information and exceptions to the blueprint or drawing

INSTRUCTOR ACTIVITY

Demonstration:

Demonstrate the use of Installation, Operation and Maintenance Manuals, and the utility of completing and filing of warranty cards.

MODULE: PROGRAMMED SYSTEM SIZING, ANALYSIS AND DESIGN

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Analyze thermal loads building loss coefficients.

(2) Select the appropriate type and size of major system components and subsystem components.

(3) Analyze the performance of the above components.

(4) Analyze life cycle costs and make decisions based upon economic maximum first cost.

(5) Design a system specifically appropriate for each individual case.

RATIONALE:

This module is optional, since all educational programs may not have access to these particular programs. However, if these programs, or other similar programs, are available, it certainly is worthwhile. Programmed analysis and sizing makes the design procedure much easier and less time intensive.

NOTE: If programs, other than those referenced in this module are used, the module notes must be changed, but the approach, presented herein, is appropriate.

REFERENCES:

(1) Solar Environmental Engineering Co., Fort Collins, Colorado, (Programs for TI-59 calculator - f-chart based).

UNIT TITLES:

(1) Survey of Programs

(2) Solar Energy Analysis

(3) Solar System Annual Performance and Life Cycle Cost

(4) Solar Heating System Optimization

(5) Solar Collector Heat Exchanger Sizing and Analysis

(6) Duct Design and Air Flow Analysis Program

(7) Thermal Storage Wall Passive Solar Heating Analysis

VOCABULARY:

Energy Analysis
Life Cycle Cost
Optimization
Thermal Conductivity/Conductance
F-Chart
Sum-Of-Years Depreciation
Relative Collector Area
SI Units
Heat Exchangers
  a. Single Pass
  b. Double Pass
  c. Four Pass

Fluid Capacitance
Transfer Units
Viscosity
Solar Radiation Parameters
Tube Velocity
Shell Velocity
Head Loss/Friction Loss
Degree Days
Water Wall
Trombe Wall
Payback Period

MODULE: PROGRAMMED SYSTEM SIZING, ANALYSIS AND DESIGN

NOTE TO INSTRUCTOR:

This module is optional and very specific in direction, method, and depth. The programs can be purchased for TI-59, HP-97, or HP-67. The TI-59 programs are the ones chosen for this module.

Brochures describing these programs, their parameters and capabilities are available upon request. See Reference 1

Unit 1. Survey Of Programs
- A. SEEC I solar energy analysis
- B. SEEC II solar annual performance and life cycle cost
- C. SEEC III solar heating system optimization
- D. SEEC IV solar collector heat exchanger sizing and analysis
- E. SEEC V duct design and air flow analysis
- F. SEEC VI thermal storage wall passive solar heating and life cycle cost
- G. SEEC VII sun angle and shading analysis

Reference 1

Unit 2. Solar Energy Analysis
- A. Thermal analysis of the building
  - 1. Describe the method and parameters of the program
  - 2. Demonstrate use of the program including variations of building design parameters
- B. Solar heating system analysis
  - 1. Based on radiation data input with meteorological data stored
  - 2. Uses f-chart method
  - 3. Demonstrate using variable collector parameters
  - 4. Demonstrate solar analysis-liquid system
  - 5. Demonstrate solar analysis-air system
  - 6. Demonstrate solar analysis-domestic hot water system

C. Life cycle economics cost analysis
  1. Based upon - how much does the system cost and how much does the system save?
  2. Compares the cost of the investment, including investment interest, to the projected savings
  3. Calculates maximum economic first cost model

STUDENT ACTIVITY

Exercise

Laboratory:

Make programs, program manual, calculator, and printer available for student use. Have the student run the programs for a site nearest your location

Unit 3. Solar System Annual Performance and Life Cycle Cost (based on annual solar fraction and relative collector area)

A. Includes sum-of-years depreciation and general inflation which are not treated in the f-chart programs
B. Collector optimization
C. Relative collector area
D. Determination of A.$_5$
E. Relative area for DHW system
F. Relative area for combined DHW and space heating system
G. Demonstrate optimal collector area calculation, solar fraction and life cycle cost for a given location
H. Vary the location and run the program again

STUDENT ACTIVITY

Laboratory:

Make programs, program manual, calculator, and printer available for student use. Have the student run the programs for a site nearest your location.

Unit 4. Solar Heating System Optimization - Basic Functions Are:
Thermal Analysis of Building
Solar Collector Choice
Solar System Sizing
Life Cycle Cost Analysis

A. Units - SI or English
B. Economics - comparison of solar system to conventional system including accepted economic practices for making such a major decision
C. Collectors - selects the collector which is most effective to the application. Also useful in fluid flow rate optimization
D. Loads - selects the construction material for each portion of a building which optimize the trade-off between construction costs and heating expense for both conventional and solar system. Also performs net heat load calculations
E. Sizing - computes directly the collector area that minimizes life cycle costs and associated annual solar fraction

STUDENT ACTIVITY

Exercise

Laboratory:

Make programs, program manual, calculator, and printer available for student use. Have the student run the program for a site nearest your location.

Unit 5. Solar Collector Heat Exchanger Sizing and Analysis (this program performs an analysis of heat exchanger variables [collector temperature, flow rate, storage temperature thermal load and fluid characteristics] and sizes the heat exchanger, physically and thermally, for the varied parameters)

A. Heat exchanger analysis program
    1. Single pass
    2. Double pass
    3. Four pass
    4. Fluid capacitance
    5. Number of transfer units
    6. Heat exchanger conductance
    7. Heat exchanger effectiveness
    8. Required area conductance
    9. Variables of hot side and cold side temperature
    10. Heat transfer rate
    11. Fluid pressure drops

B. Sizing program
    1. Hot side and cold side viscosity and thermal conductivity
    2. Inside and outside diameter of tubes
    3. Tube velocity
    4. Shell velocity
    5. Tube length
    6. Shell head loss

STUDENT ACTIVITY

Laboratory:

Make programs, program manual, calculator, and printer available for student use. Have the student run the programs for a site nearest your location.

INSTRUCTOR: Provide additional data required such as parameters of the liquid system in your laboratory.

Unit 6. Duct Design and Air Flow Analysis Programs

A. Air duct

B. Head loss

C. Blower and field test (The programs perform a variety of functions which include the effects of altitude and air temperature in the calculations. These functions include:)

1. Sizing of air ducts, round or rectangular
2. Calculation of velocity and friction (head) loss
3. Calculation of pebble-bed loss
4. Converts round duct diameters to rectangular equivalents
5. Flow rates with friction loss known or vice versa
6. Sizing and analysis of blowers
7. Calculate average velocity with varied measure head losses
8. System check out diagnostic package

STUDENT ACTIVITY

Exercise

Laboratory:

Given air system parameters with instructor provided variables, the student should run the programs and note the system performance at the varied conditions.

NOTE TO INSTRUCTOR: If your laboratory has an operational air system, have the students take measurements from this system and predict performance at varied conditions.

Unit 7. Thermal Storage Wall Passive Solar Heating Analysis (The program aids in the design of passive solar systems with Trombe walls and water walls as the basic storage configurations.)

A. Data entry program for climatological data
    1. Latitude
    2. Degree days monthly for the year
    3. Insolation monthly for the year
B. Thermal analysis program - correlations for:
    1. Water wall without insulation
    2. Water wall with night insulation

3. Trombe wall without insulation
4. Trombe wall with night insulation
5. User input:
    a. Building loss coefficient
    b. Glazed area
    c. Absorber characteristics
    d. Horizontal reflector (optional)
    e. Internal heat gain/month
6. Output:
    a. Monthly solar fraction
    b. Annual solar contribution

C. Life cycle cost analysis
    1. Comparison of solar passive heating costs to conventional heating costs including inflation
    2. Gives economic maximum first cost
    3. Life cycle cost savings
    4. Payback period

D. System analysis - reverse process to select area of glazing required to supply a given need

STUDENT ACTIVITY

Exercise

Laboratory:

NOTE TO INSTRUCTOR: Provide students with basic designs, one with Trombe wall and one with water walls. Have the students run through the programs and compare results for the two systems.

MODULE: SWIMMING POOLS, SPAS AND HOT TUBS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Discuss the design parameters that make sizing and equipment selection for a swimming pool installation different from the design parameters of a space heating and/or D.H.W. system.

(2) Describe the difference in design parameters that makes sizing and selection procedures for spa and hot tub installations different from those used for space heating and/or D.H.W. systems or swimming pool systems.

RATIONALE:

Swimming pool installations, along with DHW systems, are a major portion of the total solar systems being installed at this time. Many of the procedures, used to size and select system components, are the same as those used in DHW and space heating systems. However, it is a different application and some of the procedures are unique to swimming pools, spas, and hot tubs.

REFERENCES:

(1) Howell, Yvonne and Justin A. Bereny, Engineers Guide to Solar Energy, Solar Energy Information Services, San Mateo, California, 1979.

(2) McVeigh, J.C., Sun Power, An Introduction to the Applications of Solar Energy, Permagon Press, N.Y., 1978.

(3) Lucas, Ted, How to Build a Solar Heater, Ward Ritchie Press, Pasadena, California, 1975.

(4) Antoline, Holly L., Editor, Homeowners Guide to Solar Heating, Lane Publishing Co., Menlo Park, California, 1978.

(5) Massena, Roy P. and others, Solar Water and Pool Heating, Florida Solar Energy Center, Cape Canaveral, Florida, 1979.

(6) Applications Engineering Manual, Solaron Corporation, Denver, Colorado, 1978.

UNIT TITLES:

(1) Swimming Pools

(2) Spas and Hot Tubs

VOCABULARY:

Life Cycle Cost Analysis

Effective Sky Temperature

Conduction

Evaporation

Hot Tub

Meteorological Data

Night Sky Radiation

Convection

Radiation

Spa

$Q = MC\Delta t$

Reference 3, pp. 141-163

Unit 1. Swimming Pools

A. Application considerations
  1. Discuss the differences between swimming pool heating and domestic hot water heating or space heating
     a. Lower temperatures
     b. Higher collector efficiency - why?
     c. Pool serves as storage
     d. Very cost effective - less expensive equipment
     e. Easier installation
     f. Storage temperature lower 80°F - 85°F
     g. Pool water, exposed to sun, also serves as absorber
     h. Life cycle costs - commercial pools, very short payback period - residential pools, a little longer because of use factor
     i. May use pool circulating pump (some installations require a separate pump)

NOTE: Swimming pool systems and domestic hot water systems comprise the greatest majority of solar installations, both in dollars and numbers, in the U.S. at the time of this writing.

Reference 1, pg. 135

B. Sizing Storage Requirements
  1. Discuss methods of thermal losses from the pool
     a. Convection
     b. Conduction
     c. Radiation - explain effective sky temperature (night sky radiation)
     d. Evaporation

Reference 1, pg. 233

  2. Describe methods for reducing thermal losses
     a. Convection reduction
        1) Pool location

        2) Fences
        3) Shrubbery
        4) Wind screens
    b. Conductive reduction
        1) Insulate the sides of above ground pools
        2) Keep ground (in contact with pool) dry
        3) Below ground level pools - loss is neglible as the heat transfer swings back and forth between day and night times

    c. Radiation reduction
        1) Cover the pool at night with opaque covering
        2) Floating material such as ping pong balls, styrofoam pellets, etc.
3. Discuss average pool temperture
    a. Seasonal temperature
    b. Sources for obtaining information
    c. Pool temperature variations and how losses effect temperature

Reference 1, pg. 216

4. Calculate pool heating requirements
    a. Discuss swimming season limitations - local seasonal variations
    b. Establish upper and lower limits for solar system operation
    c. Make decision as to length of swimming season
    d. Calculate load for pool heater
       $Q = MC\Delta t$

	1) Monthly 2) Annually
Reference 3, pp. 142, 151	C. Establish circulation rate based upon losses and storage requirements 1. G.p.m., g.p.g. 2. Select pump required 3. Size booster pump if needed
Reference 5, pg. 5-1	D. Compare energy costs for heating the pool using conventional methods to heating with solar system
Reference: This course, Module on Sizing the Collector Array Reference 1, pg. 217	E. Estimate the collector performance 1. Using loss, storage parameters as load and local meteorological and radiation data, estimate the collector performance 2. Construct a collector performance curve that best fits the application
Reference 3, pg. 144	F. Discuss the possible need for a back-up system, depending upon individual preferences
Reference 3, pg. 142 Reference 5, pp. 5-17 to 5-21	G. Describe collector materials applicable to pool heating 1. Collector tubes a. Materials b. Spacing 2. Absorber materials 3. Frame or box required
Reference 1, pg. 218 Reference 5, pp. 5-31 to 5-38	H. Sizing the collector array - liquid system 1. Rule of thumb - .5 to 1 times the pool area 2. Panel collectors 3. Pipe collectors
Reference 6, pg. 800.25 and 800.26	I. Sizing the collector array - air system 1. Use the worksheet 2. Select array size 3. Select heat exchange size

NOTE: Cost of this system may not compare favorably in all applications

Reference 3, pp. 144-162
Reference 5, pp. 5-47 to 5-67
Reference 2, pp. 165-169
Review this course Module: Sizing Selection and Installation Procedures

J. Discuss and descrie system installations and maintenance
   1. Collector array - racks and risers
      a. Roof mount
      b. Ground mount
      c. Tilt angle
      d. Orientation
   2. Piping
      a. Size of pipe
      b. Size of pump/booster pump
   3. Controls
      a. Vary flow rate
      b. Manual controls
      c. Automatic controls
   4. Start up procedures
   5. Maintenance procedures

STUDENT ACTIVITY

Laboratory:

NOTE TO INSTRUCTOR: Try to arrange a field trip to a local solar swimming pool installation (motels and hotels are good possibilities).

The student will observe and take note of:

1. The application
2. Water temperture
3. Cover, if used
4. Circulation system
5. Materials used in the system
6. Controls
7. Collector type and materials
8. Collector tube spacing (or pipe spacing)

Reference 4, pp. 30, 73-75

Unit 2. Spas nd Hot Tubs

NOTE: The procedures for sizing, selection of equipment, installation, and maintenance for spas/hot tubs is very similar to D.H.W. and swimming pool systems. Temperatures and usage are the major differences. This unit will treat only the areas that are of major differences.

A. Spas
   1. Describe the usual type of enclosures
   2. Discuss storage materials
      a. Rocks, pebbles
      b. Metal container
   3. Describe methods of heat transfer to the room
   4. Discuss temperature ranges (110°F to 120°F) and safety measures
      a. Alarms
      b. Purge coils or tanks
      c. Water spray or sprinklers for cool down
   5. May require a glazed collector panel of metal construction

B. Hot tubs
   1. Describe construction materials
   2. Discuss insulation materials and where applied
   3. Depth and diameter of tub
   4. Describe circulators and stimulators
   5. Discuss purpose of tub cover
      a. Keep out trash
      b. Prevents heat loss
      c. Makes tub a passive solar collector
   6. Temperature range (105°F to 115°F)
   7. May require a glazed collector panel of metal construction

C. Discuss the possibilities of combining the collector array for swimming pool, spa and/or hot tub applications

STUDENT ACTIVITY

Laboratory:

NOTE TO INSTRUCTOR: Try to arrange a field trip to a local solar spa and/or hot tub installation (motels and hotels are good possibilities).

The student will observe and take note of:

1. The application
2. Water temperature
3. Cover, if used
4. Circulation system
5. Materials used in the system
6. Controls
7. Collector type and materials
8. Collector tube spacing (or pipe spacing)

MODULE: INSTALLATION, OPERATIONAL AND MAINTENANCE PROCEDURES

OBJECTIVES:

Upon completon of this module, the student should be able to:

(1) Prepare a start-up check list.

(2) Make the system operational following the appropriate sequential procedures.

(3) Prepare a maintenance check-list.

(4) Prepare a time based preventative maintenance schedule.

RATIONALE:

The system has been selected, sized, and installed. It is now time to make it operational. There are specific, sequential procedures that should be followed that will most likely assure the achievement of this objective. These procedures are presented, sequentially, in this module.

REFERENCES:

(1) Solar Training Manual, Phase I, Lennox Industries Educational Department, Dallas, Texas, 1979.

(2) Fundamentals of Solar Heating, U.S. Department of Energy, EG-77-C-01-4038, 1978.

(3) Applications Engineering Manual, Solaron Corporation, Denver, Colorado, 1978.

UNIT TITLES:

(1) Collector Installation Methods

(2) Storage Installation Methods

(3) Opeational Procedures - Check List

(4) Maintenance Procedures and Warranties

VOCABULARY:

Dry-Run

System Balancing Approach

Air Flow Factors

Mode Sequences

Preventative Maintenance

Proportional Controllers

Reference 1, Installation Section
Reference 2, pp. 4-49
Reference 3, Section 200 & 1200

Field trip to local collector installation and/or overhead transparencies of mounting techniques.
Use line drawings, overhead transparecies or chalkboard diagram.

Unit 1. Collector Installation Methods
- A. Collector racks
  - 1. Describe construction methods and materials
  - 2. Discuss mounting
    - a. Roof mounting
    - b. Ground mounting
    - c. Remote mounting
- B. Circulation patterns
  - 1. Describe liquid system flow patterns (collector)
  - 2. Describe air system flow patterns (collector)
  - 3. Demonstrate manifold connections for series and parallel systems
  - 4. Discuss characteristics of direct and reverse return flow patterns
- C. Collector mounting
  - 1. Describe a variety of mounting methods and fasteners
  - 2. Discuss the effects of thermal expansion and contraction of collector materials

NOTE: Be certain there is room between collector panels for thermal expansions

Unit 2. Storage installation methods
- A. Within the structure
  - 1. Liquid storage
  - 2. Air storage
- B. Outside the structure
  - 1. Above ground
  - 2. Below ground

STUDENT ACTIVITY

Exercise

Laboratory:

Given the possible stagnation temperature difference of the collectors and the collector absorber and framing material, the student should calculate the required spacing between collector panels.

NOTE: Stagnation temperature difference is the difference between the temperature of the panels at time of mounting and possible stagnation temperature.

Reference 1, Installation Section, pp. 45-49

Unit 3. Operational Procedures - Check List

A. Start-up procedures
   1. Check manufacturers installation manual for procedures. Make certain that all installation processes are complete
   2. Liquid system
      a. Flush out collector loop
      b. Flush out storage system
      c. Fill and pressure test for leaks, make any necessary repairs
      d. Drain collector loop and charge with collector loop fluid. Leave air vents at top of collector return manifold open during the charging process, closing them as liquid begins to flow from them

NOTE: Most manufacturers provide charging procedure instructions. Follow them "to the letter"

      e. Be sure all valves, except drain valves, are open during the charging process
      f. Dry run the control system. Make note of any malfunctioning controls or controlled devices. Make any necessary repairs and dry run again until control system functions properly

No references available at this time.

3. Air system
   a. Check manufacturer's installation manual. Make certain that all installation processes are complete
   b. Install temporary air filter in supply outlet from pebble bed
   c. Start teh fan/blower, allowing it to catch debris in the temporary filter while checking for air leaks at duct joints (collector loop and load loop)
   d. Using an inclined manometer, check the external static pressure at the pebble bed, fan/blower side and compare the reading to the rating of the fan/blower
   e. Repeat step d.
   f. Dry run the control system through all modes. Note any malfunctions and repair as needed. Dry run the control system until all mode sequences are operating properly

Reference 2, pp. 10-4, 10-5

B. System balancing
   1. Determine balancing approach
   2. Note any variations from blueprint
   3. Makeup worksheets similar to figure 10-7
   4. If available, follow procedure outlined by system manufacturer. If not, prepare a list of:

        - a. Fan/blower performance data
        - b. Air flow measurement factors
    5. Plan balancing so that back dampers are used only for final tuning of the system

INSTRUCTOR ACTIVITY

Demonstration:

1. Select an operational system - air or liquid - and demonstrate start up procedures described in this unit. If this demonstration would present problems such as making the system unavailable for the next instructor, or possible damage to your particular system, demonstrate as many of the procedures as you can.
2. Prepare a start-up check list for the system.

Reference 2, pg. 10-5

Unit 4. Maintenance Procedures and Warranties

A. Periodic maintenance
    1. Change air filters
    2. Change liquid filters
    3. Check antifreeze solution annually
    4. Check fan/blower belts and lubricate
    5. Lubricate pumps
    6. Check liquid level weekly for first month

Reference 2, pp. 10-6 to 10-9

B. Prepare an inspection list for the following components:
    1. Collectors
        - a. Glazing
        - b. Absorber plates
        - c. Tubing
    2. Piping
    3. Ducts
    4. Heat storage vessels
    5. Liquid
    6. Air
    7. Air handlers
    8. Pumps
    9. Valves

    10. Dampers
    11. Sensors
    12. Differential thermostat
    13. Proportional controllers

C. Describe potential problems with the components above

D. Discuss preventative maintenance measures for those items listed in B above

STUDENT ACTIVITY

Laboratory:

1. Prepare an operational and maintenance procedures check list for solar system (air and/or liquid) in your lab (or one available to you for this purpose).
2. Describe potential system problems from lack of appropriate maintenance.
3. Describe preventative maintenance procedures that will minimize those problems.

MODULE: SOLAR SYSTEM COMPONENTS - OVERVIEW AND REVIEW

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Draw and label solar schematic diagrams.

(2) Determine collector efficiency.

(3) Compare performance of collectors.

(4) Measure radiation incident to the collector.

(5) Describe active and passive storage methods.

(6) Discuss and analyze the function and relationship of each system component.

RATIONALE:

Several months may have passed by since your studies in Energy Science, Intro to Solar Energy and Collectors and Energy Storage. The intent of this module is to review major topics from those courses and reinforce your perspective as to what constitutes a solar system and the parameter affecting system decisions.

REFERENCES:

(1) Energy Science I and II Topics - Tippens, A.E., Applied Physics, McGraw-Hill, Book Co., N.Y., 1978.

(2) Introduction to Solar Energy Topics - McDaniels, D.K., The Sun, John Wiley and Sons, N.Y., 1979.

(3) Collectors and Energy Storage Topics - Solar Heating and Cooling of Residential Buildings, U.S. Department of Commerce.

(4) Solar Energy for Buildings Handbook, D.O.E., ORO-5362-T1.

UNIT TITLES:

(1) Solar Radiation Characteristics - Review

(2) Collector System - Review

(3) Storage System - Review

(4) Discuss Circulation System Components - Review

(5) Describe Control System Components - Review

VOCABULARY:

Air Collectors
Liquid Collectors
Flow Pattern
Electro - Mechanical Controls
Circulation Rates
Head Loss
Visible Spectrum
Wave Length
Frequency
Direct Radiation
Diffuse Radiation
Heat Exchangers
Temperature Controls
Pressure Controls
Centrifugal Pumps
Duct
Thermal Storage
Active System
Passive System
Pyranometer
Pyrheliometer

Review from:
Energy Science Topics
Intro to Solar Energy Topics
Collectors and Energy Storage Topics

Line drawings, slides or overhead transparencies would be useful in demonstrating these characteristics and relationships.

Unit 1. Solar Radiation Characteristics - Review

- A. Discuss characteristics of
    - 1. Origin
    - 2. Short wave radiation
    - 3. Long wave radiation
    - 4. Wave length/frequency
    - 5. Global (total) radiation
    - 6. Beam radiation
    - 7. Diffuse radiation
    - 8. Solar constant
    - 9. Effects of air mass, clouds and pollutants on radiation received on earth
- B. Discuss sun/earth relationship
    - 1. Seasonal variations -
    - 2. Sun altitude and azimuth
    - 3. Effects of changes in the angle of incidence
- C. Describe sun/collector relationship
    - 1. Latitude and sun angle
    - 2. Collector tilt angle
    - 3. Non-tracking collectors
    - 4. Tracking collectors
    - 5. Effects of variations from collector facing solar south
- D. Review solar radiation data sources
    - 1. ASHRAE
    - 2. National weather services - local
    - 3. National weather center, Ashville, N.C.
    - 4. Climatic atlas of the U.S.
- E. Solar radiation measuring instruments
    - 1. Pyranometers - review types
    - 2. Pyrheliometer - review types

Review of Collectors and Energy Storage Topics

Unit 2. Collector Systems - Review

- A. Liqid system collectors - discuss materials, construction, components and flow patterns

Printed handout of line drawings or overhead transparency of the Collection System, Air and Liquid

1. Flat plate collectors
2. Concentrating collectors - parabolic, spherical and mirrors, concentration ratio
3. Tubular
    a. Atmospheric
    b. Evacuated
4. Tracking and non-tracking collector systems
5. Collector systems
    a. Closed loop
    b. Drain-down
    c. Drain-back

B. Air system collectors - discuss materials, components, construction and flow patterns
    1. Layered glass
    2. Black absorber plate

C. Collector performance - active system review
    1. Effect of variables
        a. Construction
        b. Insolation
        c. Ambient conditions

Line drawings, slides, or overhead transparencies of Passive Collection Method. Graphic Appendices PA-1 through PA-7-T Review of Collectors and Energy Storage Topics

D. Passive collection
    1. Direct
    2. Indirect

Schematic diagram of system showing energy from colletor to storage. Printed handout or overhead transparency.

Unit 3. Storage System - Active

A. Liquid storage - active
    1. Water
    2. Water/glycol
    3. Phase change compounds
    4. Specific heat of 1, 2 and 3
    5. Insulation
    6. Storage vessel materials and construction

B. Air storage - active
    1. Rocks
    2. Pebbles
    3. Crushed stone
    4. Phase change compounds
    5. Specific heat of 1, 2, 3, and 4
    6. Storage vessel materials and construction

Illustrated graphic overlays showing winter sun position and summer sun postion.

Reference graphics from Unit 2 A

- C. Passive storage options
    - 1. Thermal walls
        - a. Trombe
        - b. Water
        - c. Masonry
    - 2. Mass requirements
        - a. Thermal lag
        - b. Temperature variations
    - 3. Thermal roof storage
    - 4. Attached sunspaces
    - 5. Insulation and thermal envelope
    - 6. Construction materials
- D. Chemical storage
    - 1. Eutectic salts
    - 2. Batteries
    - 3. Photo - chemical
    - 4. Oils, waxes, and other compounds
    - 5. Containers

Review of Collectors and Energy Storage Topics

Schematic diagram of liquid system, including hydromic devices and piping.

Reference 4, pg. 152

Unit 4. Discuss Circulation System Components - Review

- A. Liquid circulation system
    - 1. Piping requirements
        - a. What type
        - b. What size
        - c. Friction loss of piping and fittings
    - 2. Pump requirements
        - a. GPM rate
        - b. Head capacity
    - 3. Heat exchangers
        - a. Types
        - b. Transfer fluids
        - c. Transfer coefficient units
    - 4. Protective devices
        - a. Air vents
        - b. Thermal protection
        - c. Flow protection
        - d. Electrical overload protection
        - e. Pressure protection

Schematic diagram of air system with these components.

- B. Air circulation system
    - 1. Fans/blowers
    - 2. Heat exchangers
    - 3. Ducts and duct components
    - 4. Protective devices

Review of Collectors and Energy Storage Topics

Unit 5. Describe Control System Components - Review

Slides, line drawings or overhead trnsparencies (overlays) demonstrating controls/controlled devices.

A. Discuss control theory and control logic
B. Controllers
  1. Thermostats
  2. Pressurestats
  3. Aquastats
  4. Electro-mechanical devices
C. Controlled devices (actuators)
  1. Motors
  2. Dampers
  3. Valves
  4. Pumps
  5. Fans/blowers
  6. Purge coils
  7. Drain devices

ACTIVITY

Exercise I

Assignment:

List the advantages and disadvantages of:

1. Flat plate collectors
   a. Liquid
   b. Air
2. Concentrating (focusing) collectors
3. Liquid storage
4. Rock storage.

STUDENT ACTIVITY

Lab Exercise I

Laboratory:

Laboratory Materials and Tools:

Flat plate collector performance curve, spectral pyranometer (or other radiation measuring instruments if spectral pyranometer is not available. Be sure and consider margin of error if other instruments are used), an operational liquid domestic hot water system, thermometers and flow meter.

Lab Procedure:

1. The student should measure temperature in and temperature out of the collector.
2. Record the mass flow rate, from the flow meter, minutes of time.
3. Measure global radiation incident upon the collectors glazing.
4. Using formula $Q = MC\Delta t$, calculate the heat transfer rate of the absorber plate.
5. Calculate collector efficiency.

6. Using data recorded and collector performance curve, calculate collector efficiency.
7. Compare efficiency from step 5 with that of step 6, analyze and write conclusions.

STUDENT ACTIVITY	Assignment:
Exercise II	The student should draw and label a solar system schematic diagram (minimum components and relationship to be established by instructor).
Exercise III	A teacher provided test on Collection Loop (air and liquid) Components and Storage System Components.
STUDENT ACTIVITY	Laboratory:
Lab Exercise II Laboratory Materials and Tools:	An operational liquid system, an operational air system.
Laboratory procedure:	The student should identify each system component and describe its function and relationship to the total system.

SYSTEM SIZING, DESIGN AND RETROFIT

Representative Labs

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 1: Basic Solar Systems

1. Draw a schematic diagram of:
   a. Space heating and DHW closed loop liquid system.
   b. Space heating and DHW air system.
   c. DHW drain down system.
   d. DHW drain back system.

2. Label the components of each of the above systems.

3. Briefly describe the function of each of the components above.

4. List the advantages (in one column) and disadvantages (in another column) of:
   a. Flat plate collectors - liquid and air
   b. Concentrating collectors
   c. Storage - liquid and rock

Lab 2: Design Considerations

The designer of a solar system is faced with many limitations and considerations that become an integral part of the design process. The preliminary investigative phase of the design is of utmost importance. Using the information given in the lecture on Design Considerations and Parameters, visit a residential construction site and:

1. List the building considerations that might affect the application(s) decision.
2. Decide which application(s) would be appropriate and give the rationale for your decision.
3. Select collector type best suited for the application(s) and where they should be mounted.
4. Determine the tilt angle required for optimum performance of the system.
5. Determine the preferable type of storage and where best location would be likely.
6. Draw a sketch of the plot plan, including outline of floor plan and possible solar obstructions or shading in one color. Over this plan superimpose the collector array and storage location in different colors.

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 3: Load Calculation Features V-111

There are certain factors that are common to load calculations for residential applications. The following lab will develop analysis skills that will be useful in making instantaneous load calculations. The second part of this lab will provide data for making a comparison of the calculated instantaneous load at design temperatures and the actual load at a given condition.

1. Make a sketch of the solar demo house including wall, floor, ceiling and roof construction. Also note door and window construction and dimensions. Turn on the heaters and close the door before leaving.

2. Calculate the heat loss in Btu/hr. for the building at 16°F outside design temperature and 66°F inside design temperature.

3. Using the Btu/hr. heat loss for the building, 60°T.D. and total area (sq. ft.) exposed to ambient, calculate the Building U factor (heat loss co-efficient).

4. By this time the temperature in the demo house should be stabilized. Measure and record inside and outside dry bulb temperature. Power input to heaters and temperature differences provide data for determining the actual building U factors of _______________ $Btu/ft^2/^{\circ}F/hr$.

5. What conclusions can you draw from analyzing the difference in calculated and actual building loss/hr.

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 4: Heating Load V-113

A thorough understanding of heat loss/gain in a building is an integral part of the sizing and design process. The following lab will reinforce these concepts.

1. Using floor plan (attached), outside design temperature - 16°F, inside design temperature - 66°F, infiltration air - .75 air changes/hr. (Show your work).
   a. Calculate net area (A) of walls, doors, windows, floor and ceiling for each type of construction exposed to unconditioned space.
   b. Calculate U factor for each area in A above.
   c. Calculate the heat loss for each area and total transmission losses. Btu/hr = UA(T_i-T_o)
   d. Calculate infiltration losses. (Btu/hr. = .018 x T.D. x air changes/hr)
   e. Add transmission loss to infiltration loss. Calculate duct loss and add to transmission and infiltration total.
   f. Subtract internal gains, where appropriate, for total building heat loss rate.

2. Convert the heat loss rate (Btu/hr) to Btu/Degree Day.

3. Construct a tabular worksheet that will simplify these calculations in the future (for your use).

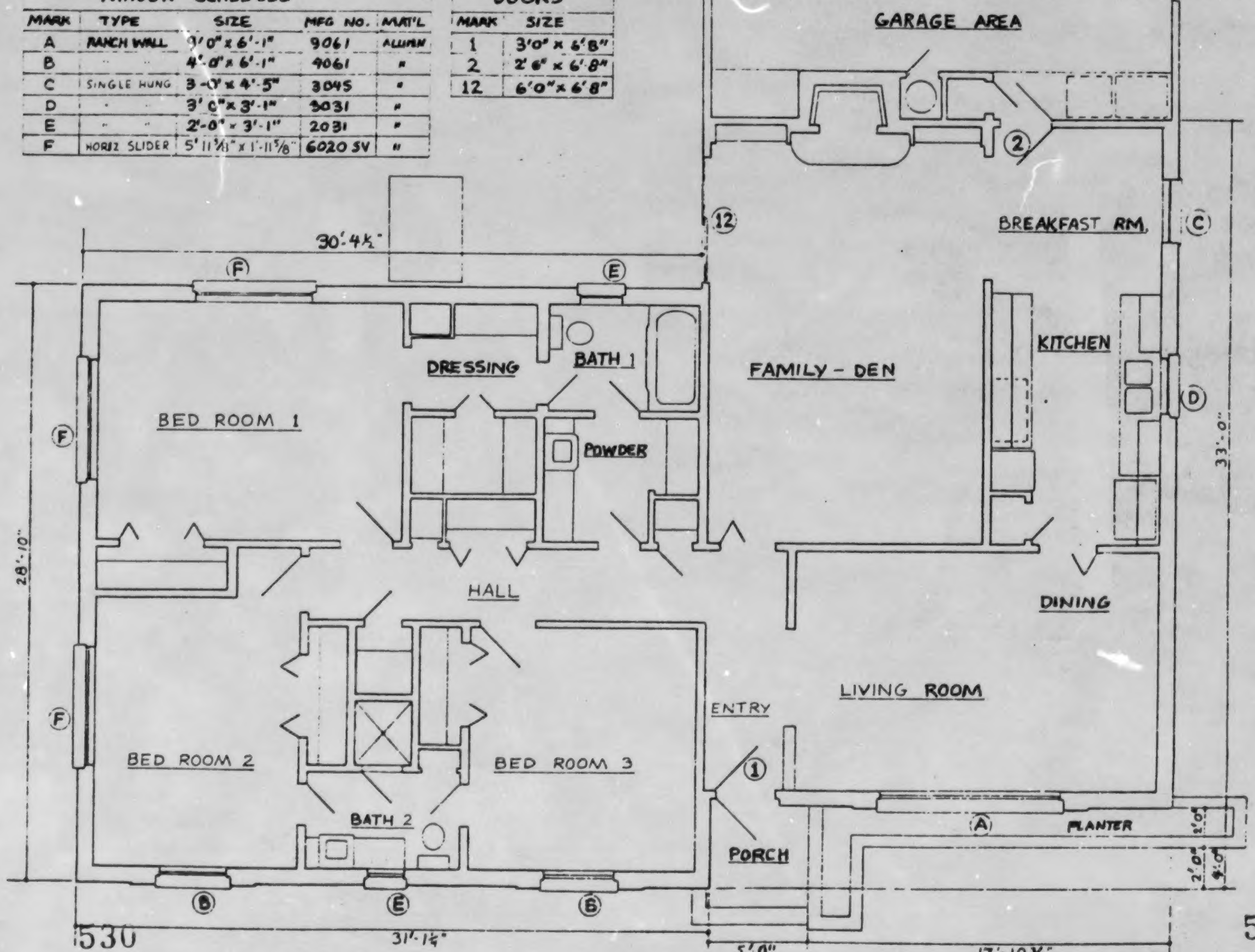
4. Using Degree Day tables, what is the space heating load for this structure?
   January load ____________________
   Annual load ____________________

4 person residence
Infiltration - .75 Air Changes/hr.
Brick Veneer, R-13 Wall

Slab Floor
Ceiling - 6" (R-19) insulation under
Ventilated Attic - Light roof.
Duct - IN Attic with 2" insulation

WINDOW SCHEDULE				
MARK	TYPE	SIZE	MFG NO.	MAT'L
A	RANCH WALL	9'0" x 6'-1"	9061	ALUMN
B	" "	4'-0" x 6'-1"	4061	"
C	SINGLE HUNG	3-0" x 4'-5"	3045	"
D	" "	3' 0" x 3'-1"	3031	"
E	" "	2'-0" x 3'-1"	2031	"
F	HORIZ SLIDER	5' 11 3/8" x 1'-11 5/8"	6020 SV	"

DOORS	
MARK	SIZE
1	3'0" x 6'8"
2	2'6" x 6'8"
12	6'0" x 6'8"


GARAGE AREA
②
⑫
BREAKFAST RM.
Ⓒ
KITCHEN
Ⓓ
FAMILY - DEN
30'-4½"
Ⓕ
Ⓔ
DRESSING
BATH 1
POWDER
BED ROOM 1
Ⓕ
28'-10"
33'-0"
HALL
DINING
LIVING ROOM
ENTRY
Ⓕ
BED ROOM 2
BED ROOM 3
①
BATH 2
PORCH
Ⓐ
PLANTER
2'-0"
2'-0"
4'-0"
Ⓑ
Ⓔ
Ⓑ
31'-1¼"
5'0"
17'-10¾"

Lab 5: Cooling Load

In some climates, particularly in the south and southwest United States, the auxiliary system must make some provisions for cooling. In a total Solar environmental control system, Passive cooling may be a large part of the system, but, as a general rule in these locales, conventional cooling - electric or absorption - is a part of the package. Cooling load calculation skills are required for the successful technician.

1. Using the attached floor plan, outside design temperature - 100°F, inside design temperature - 78°F, infiltration air - .75 air changes/hr. (Show your work).

   a. Calculate Net area of walls, doors, windows, floor and ceiling for each type of construction exposed to unconditioned space.
   b. Calculate U factor for each area in A above.
   c. Calculate the heat gain for each area and sum for total transmission gain. (Btu/hr = U $A(T_o - T_i)$)
   d. Calculate solar gain and add to transmission gain. (Solar gain on walls, windows and doors).
   e. Calculate infiltration gains and add to total from D above. (.018 x T.D. x air changes/hr)
   f. Add gain from people, appliances and lighting to total from E above.
   g. Calculate duct gain and add to sum from F.
   h. Multiply total from G times 1.3 for sensible plus latent gains. This figure represents the total cooling load.

2. Convert Btu/hr. to Btu/Degree Day using 78° as the degree day base.

3. Calculate the Btu/D.D for
   July ____________________
   Annual __________________

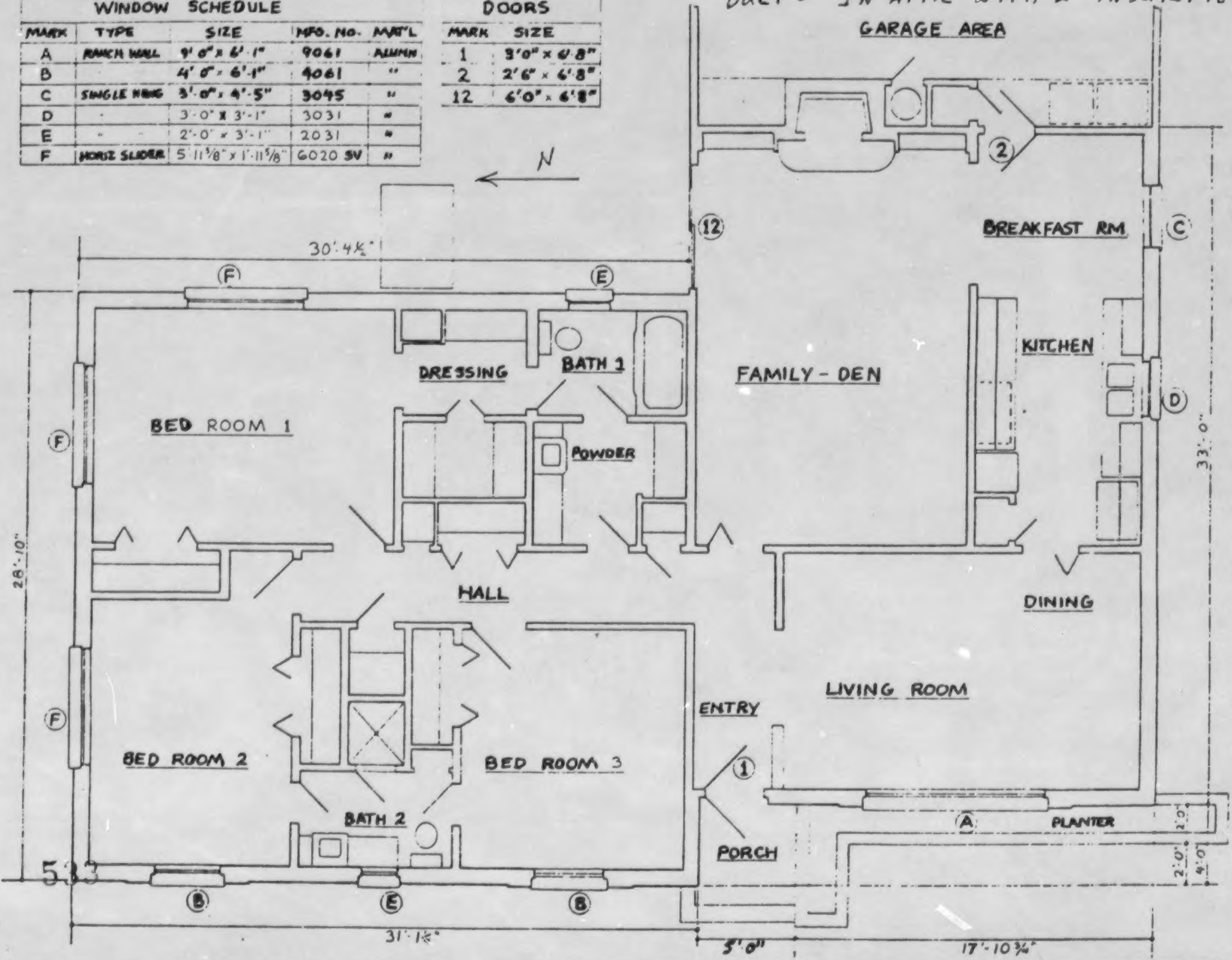
4. Construct a tabular worksheet that will enable you to make future load calculations for cooling more rapidly.

4 person residence
Infiltration - .75 Air Changes/hr.
Brick Veneer, R-13 Wall

Slab Floor
Ceiling - 6" (R-19) insulation under
Ventilated Attic - Light roof
Duct - IN Attic with 2" insulation

WINDOW SCHEDULE				
MARK	TYPE	SIZE	MFG. NO.	MAT'L
A	RANCH WALL	9'0" x 6'-1"	9061	ALUMN
B		4'0" x 6'-1"	4061	"
C	SINGLE HNG	3'-0" x 4'-5"	3045	"
D	"	3'-0" x 3'-1"	3031	"
E	"	2'-0" x 3'-1"	2031	"
F	HORIZ SLIDER	5'-11 5/8" x 1'-11 5/8"	6020 SV	"

DOORS	
MARK	SIZE
1	3'0" x 6'8"
2	2'6" x 6'8"
12	6'0" x 6'8"


N
GARAGE AREA
②
⑫
BREAKFAST RM
Ⓒ
30'-4½"
Ⓕ
Ⓔ
DRESSING
BATH 1
FAMILY - DEN
KITCHEN
Ⓓ
BED ROOM 1
Ⓕ
POWDER
28'-10"
33'-0"
HALL
DINING
LIVING ROOM
ENTRY
Ⓕ
BED ROOM 2
BED ROOM 3
①
BATH 2
Ⓐ
PLANTER
PORCH
2'0"
2'0"
4'0"
Ⓑ
Ⓔ
Ⓑ
31'-1½"
5'0"
17'-10¾"

Lab 6: Short-form Load Calculation

Short form load calculations are essential in making the initial estimate of the solar sizing requirements. They also provide a base for auxiliary equipment selection. This lab will develop those skills required and aid in making rapid decisions. Also, it will provide a check list of minimum data required for sizing estimates.

1. Using the short form, data sheet and floor plan provided, calculate the heating load at 55° T.D. for Irving, Texas.

2. Calculate the cooling load at 22° T.D. for Irving, Texas.

FORM 219R 5-76

LAB: SYSTEM SIZING, DESIGN AND RETROFIT V-123

Texas Power & Light Company

HEATING AND COOLING ESTIMATE
RESIDENTIAL

Customer ______________________

Address ______________________

Town ______________ District ______________

Prepared by: ______________ Date ______________

DESIGN CONDITIONS

COOLING D.B. °F.
Outside Temp. ________
Inside Temp. ________
Temp. Diff. ________

HEATING D.B. °F.
Inside Temp. ________
Outside Temp. ________
Temp. Diff. ________

INSULATION
Ceiling ________
Wall ________
Floor ________
Window ________

HOUSE FACES
☐ North
☐ East
☐ South
☐ West

OVERHANG OR SHADING
North ________
East ________
South ________
West ________

CONSTRUCTION	COOLING FACTOR							HEATING FACTOR	QUANTITY	COOLING BTUH	HEATING BTUH
1. GLASS—SOLAR GAIN Windows—Doors (Sq. Ft. (*Note A)	No Shading	Inside Shading & Overhang					Outside Shades				
		0'	1'	2'	3'	4'					
North	32	14	0	0	0	0	0				
Northeast	50	23	21	19	19	17	17				
East	50	23	20	19	17	14	13				
Southeast	80	36	26	19	8	0	21				
South	100	45	33	10	0	0	26				
Southwest	155	70	51	39	17	0	42				
West	190	86	82	80	67	57	57				
Northwest	128	58	54	51	51	49	37				
Horizontal	185										

	Uo	DESIGN D.B. TEMP. DIFFERENTIAL								QUANTITY	COOLING BTUH	HEATING BTUH
		20	22	25	30	65	60	55	50			
2. GLASS TRANSMISSION (Sq. Ft.)		Uo x TD				Uo x TD						
Standard—Single Glazing	1.13	22.6	24.9	28.2	33.9	73.4	67.8	62.2	56.5			
Insulating—Double Glazing	.78	15.6	17.2	19.5	23.4	50.7	46.8	42.9	39.0			
Storm Window	.67	13.4	14.7	16.8	20.1	43.6	40.2	36.8	33.5			
Storm or Insulating Glass with Thermal Break	.56	11.2	12.3	14.0	16.8	36.4	33.6	30.8	28.0			
3. DOORS—(Sq. Ft.)		Uo x TD				Uo x TD						
Solid Wood or Hollow Core	.55	11.0	12.1	13.8	16.5	35.8	33.0	30.3	27.5			
Wood with Storm Door	.34	6.8	7.5	8.5	10.2	22.1	20.4	18.7	17.0			
Metal with 1½" Urethane	.11	2.2	2.4	2.8	3.3	7.2	6.7	6.1	5.6			
4a. FLOOR: SLAB (Linear Ft. Exposed Edge)		Uo x zero				Uo x TD						
No Edge Insulation	.81					52.6	48.6	44.6	40.5			
R -4 Edge Insulation	.68					44.2	40.8	37.4	34.0			
R -7 Edge Insulation	.55					35.8	33.0	30.2	27.5			
4b. FLOORS: ENCLOSED CRAWL SPACE (Sq. Ft.)		Uo x zero				Uo x (TD-20)						
No Insulation	.270					12.2	10.8	9.4	8.1			
R -7 Insulation	.093					4.2	3.7	3.2	2.8			
R-11 Insulation	.073					3.3	2.9	2.6	2.2			
R-13 Insulation	.060					2.7	2.4	2.1	1.8			
R-19 Insulation	.046					2.1	1.8	1.6	1.4			
R-22 Insulation	.039					1.8	1.6	1.4	1.2			
4c. FLOORS: OPEN CRAWL SPACE (Sq. Ft.)		Uo x (TD-5)				Uo x TD						
No Insulation	.374	5.6	6.4	7.5	9.4	24.3	22.4	20.6	18.7			
R -7 Insulation	.103	1.5	1.8	2.1	2.6	6.7	6.2	5.7	5.2			
R-11 Insulation	.073	1.1	1.2	1.5	1.8	4.7	4.4	4.0	3.6			
R-13 Insulation	.064	1.0	1.1	1.3	1.6	4.2	3.8	3.5	3.2			
R-19 Insulation	.046	0.7	0.8	0.9	1.2	3.0	2.8	2.5	2.3			
R-22 Insulation	.041	0.6	0.7	0.8	1.0	2.7	2.5	2.3	2.0			
5. WALLS—(Sq. Ft.) NET		Uo x TD				Uo x TD						
No Insulation—Solid Masonry	.389	7.8	8.6	9.7	11.7	25.3	23.3	21.4	19.5			
No Insulation—Wood Siding	.320	6.4	7.0	8.0	9.6	20.8	19.2	17.6	16.0			
No Insulation—Brick Veneer	.240	4.8	5.3	6.0	7.2	15.6	14.4	13.2	12.0			
R -5 Insulation	.128	2.6	2.8	3.2	3.8	8.3	7.7	7.0	6.4			
R -7 Insulation	.109	2.2	2.4	2.7	3.3	7.1	6.5	6.0	5.5			
R-11 Insulation	.075	1.5	1.7	1.9	2.3	4.9	4.5	4.1	3.8			
R-13 Insulation	.065	1.3	1.4	1.6	2.0	4.2	3.9	3.6	3.3			
R-16 Insulation	.054	1.1	1.2	1.4	1.6	3.5	3.2	3.0	2.7			
R-19 Insulation	.047	0.9	1.0	1.2	1.4	3.1	2.8	2.6	2.4			
R-24 Insulation	.038	0.8	0.8	1.0	1.1	2.5	2.3	2.1	1.9			

V-124 LAB: SYSTEM SIZING, DESIGN AND RETROFIT

CONSTRUCTION	Uo	COOLING FACTOR				HEATING FACTOR				QUANTITY	COOLING BTUH	HEATING BTUH
		DESIGN D.B. TEMP. DIFFERENTIAL										
		20	22	25	30	65	60	55	50			
6a. CEILINGS—WITH ATTIC (Sq. Ft.) (*Note B)		Uo x (TD + 40)				Uo x TD						
No Insulation	.598	35.9	37.1	38.9	41.9	38.9	35.9	32.9	29.9			
R-4 Insulation	.176	10.6	10.9	11.4	12.3	11.4	10.6	9.7	8.8			
R-7 Insulation	.114	6.8	7.1	7.4	8.0	7.4	6.8	6.3	5.7			
R-11 Insulation	.079	4.7	4.9	5.1	5.5	5.1	4.7	4.3	4.0			
R-19 Insulation	.048	2.9	3.0	3.1	3.4	3.1	2.9	2.6	2.4			
R-22 Insulation	.042	2.5	2.6	2.7	2.9	2.7	2.5	2.3	2.1			
R-26 Insulation	.036	2.2	2.2	2.3	2.5	2.3	2.2	2.0	1.8			
R-30 Insulation	.032	1.9	2.0	2.1	2.2	2.1	1.9	1.8	1.6			
R-33 Insulation	.029	1.7	1.8	1.9	2.0	1.9	1.7	1.6	1.5			
R-38 Insulation	.025	1.5	1.6	1.6	1.8	1.6	1.5	1.4	1.2			
6b. CEILINGS—NO ATTIC (Sq. Ft.) (*Note B)		Uo x (TD + 45)				Uo x TD						
No Insulation	.470	30.6	31.5	32.9	35.3	30.6	28.2	25.9	23.5			
R-4 Insulation	.160	10.4	10.7	11.2	12.0	10.4	9.6	8.8	8.0			
R-5 Insulation	.130	8.5	8.7	9.1	9.8	8.5	7.8	7.2	6.5			
R-7 Insulation	.109	7.1	7.3	7.6	8.2	7.1	6.5	6.0	5.5			
R-11 Insulation	.076	4.9	5.1	5.3	5.7	4.9	4.6	4.2	3.8			
R-19 Insulation	.047	3.1	3.1	3.3	3.5	3.1	2.8	2.6	2.4			
R-26 Insulation	.035	2.3	2.3	2.4	2.6	2.3	2.1	1.9	1.8			
R-30 Insulation	.031	2.0	2.1	2.2	2.3	2.0	1.9	1.7	1.6			
7. SENSIBLE INFILTRATION VOL. METHOD (Cu. Ft.) (*Note C)		Uo x TD				Uo x TD						
0.50 Well Above Standard	.009	0.18	0.20	0.22	0.27	0.58	0.54	0.50	0.45			
0.67 Above Standard	.012	0.24	0.26	0.30	0.36	0.78	0.72	0.66	0.60			
0.75 Standard	.013	0.26	0.29	0.32	0.39	0.84	0.78	0.72	0.65			
1.00 Average	.018	0.36	0.40	0.45	0.54	1.17	1.08	0.99	0.90			
1.50 Below Average	.027	0.54	0.59	0.68	0.81	1.76	1.62	1.48	1.35			
2.00 Well Below Average	.036	0.72	0.79	0.90	1.08	2.34	2.16	1.98	1.80			
8. PEOPLE—SENSIBLE ONLY (Avg. No.)		250										
9. SUB TOTAL—SENSIBLE HEAT (Total 1 through 8)												
DUCT FACTOR (From Table below)											X ______	X ______
10 TOTAL SENSIBLE—INCLUDING DUCT LOSS (Multiply Line 9 Sub Total by Duct Factor)												

11. INFILTRATION—LATENT HEAT (Cu. Ft.)	FACTOR		QUANTITY	COOLING BTUH	HEATING BTUH
0.50 Well Above Standard	0.332				
0.67 Above Standard	0.444				
0.75 Standard	0.497				
1.00 Average	0.633				
1.50 Below Average	0.994				
2.00 Well Below Average	1.333				
12. PEOPLE—LATENT HEAT (Avg. No.)	200				
13. TOTAL LOAD BTUH (Total 10, 11, 12)					
14. UNITARY COOLING EQUIPMENT REQUIREMENT (BTUH): Line 10 x 1.25					
15. INSTALLED EQUIPMENT CAPACITY (BTUH) Use Larger of Line 13 or Line 14					
		(*Note G)		TONS	KW

COST OF OPERATION ESTIMATE FOR HEATING AND COOLING

COOLING (Line 13) MBTUH ÷ FCR = KW × Hours = KWH/Season (@) $ ______/KWH = $ /Season
Use 1700 Hrs. for 75 Maintained
Use 1400 Hrs. for 78 Maintained
(Note D)

HEATING ________ (Line 13) MBTUH × ______ (*Note E) KWH/MBTU ÷ ______ S.P.F. = ________ KWH/Season (@) $ ______ /KWH = $ ______ /Season
Use 1.0 if Furnace
Use 2.0 if Heat Pump
(Note F)

Total $ __________ /Year

DUCTWORK LOCATION	INSUL. THICKNESS	COOLING FACTOR	HEATING
Attic—vented	1"	1.15	1.25
—vented	2"	1.10	1.15
—unvented	1"	1.20	1.20
—unvented	2	1.15	1.10
Crawl space—vented	2"	1.10	1.15
—unvented	1"	1.05	1.10
Within conditioned area	1"	1.00 1.29	1.00 1.25

*Note A 1. Use only the one largest Solar Gain
2. Multiply the Factors by .90 for Plate Glass .85 for double glass
3. No Solar Gain is used if overhang exceeds 4', or if glass is shaded by permanent structure
*Note B For light colored roof Multiply COOLING Factor by .75
*Note C See infiltration Construction Definitions (See pad back)
*Note D Full load equivalent run hours
*Note E Annual Heating Consumption Factor from TP&L Service Area Weather Data (See pad back)
*Note F S.P.F. is Seasonal Performance Factor of Heating Equipment
*Note G [illegible]

INFILTRATION CONSTRUCTION DEFINITIONS
(AS RELATED TO E-OK PROGRAM)

METHOD OF REDUCING INFILTRATION OF UNCONDITIONED AIR
(Range: from 0.67 to 1.75 All Changes Per Hour)

INFILTRATION REDUCED BY:	E-OK POINTS	AIR CHANGES SAVED PER HOUR
A. Soleplate Sealed (33%)	13	0.3564
B. Wiring & Plumbing Holes and Furrdowns Sealed (26%)	10	0.2808
C. Exterior Doors & Windows Weather Stripped (7%)	3	0.0756
D. Exterior Door & Window Rough Openings Caulked (17%)	6	0.1836
E. Attic Access in Conditioned Space Weather Stripped (2%)	2	0.0216
F. Outside Sheathing Holes Sealed and Polyethylene Film Installed (7%)	3	0.0/56
G. Ventless or Dampered Range Hood Installed (8%)	3	0.0864
TOTAL	40	1.0800

STRUCTURAL AIR CHANGES PER HOUR AS RELATED TO E-OK POINTS

AIR CHANGES PER HOUR	E-OK POINTS
0.50	40
0.67	40
0.75	36
1.00	27
1.25	18
1.50	9
1.75	0

TP&L SERVICE AREA WEATHER DATA

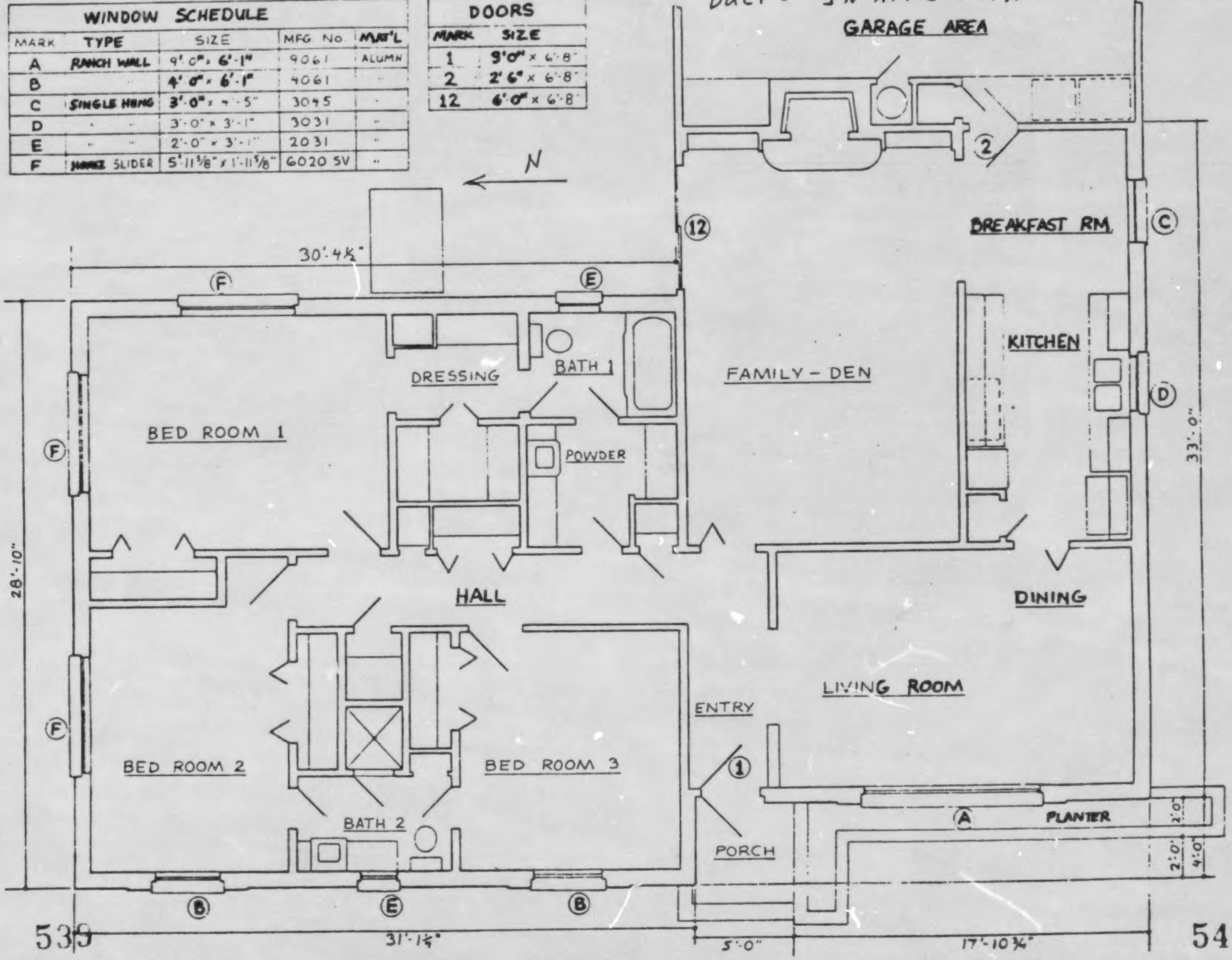
	TOWN	OUTSIDE TEMPERATURE DESIGN (DEG F) **SUMMER 1%	2½%	WINTER	HEATING DEGREE DAYS BASE 65°	ANNUAL HEATING CONSUMPTION FACTOR IN KWH&MBTU FOR NOTED ROOM TEMPERATURE 70°	71°	72°	73°	74°	75°
CENTRAL DIVISION	Cleburne	102	100	10	2100	185	202	215	231	246	262
	Farmers Branch	101	99	10	2300	202	221	235	253	270	287
	Euless	102	100	10	2350	207	225	240	259	276	293
	Irving	102	100	10	2300	202	221	236	253	270	287
	Mesquite	101	99	10	2300	202	221	235	253	270	287
	Garland	101	99	10	2300	202	221	235	253	270	287
	Mineral Wells	102	100	10	2450	224	244	260	279	298	317
	Plano	101	99	10	2300	202	221	235	253	270	287
	Richardson	101	99	10	2300	202	221	235	253	270	287
	Waxahachie	101	99	10	2450	224	244	260	279	298	317
	Ennis	101	99	10	2450	224	244	260	279	298	317
	Lancaster	101	99	10	2300	202	221	235	253	270	287
	*Weatherford (Parker Co)	102	100	10	2850	250	273	292	313	334	355
	*Ft. Worth (Tarrant Co)	102	100	10	2350	207	225	240	259	276	293
	*Dallas (Dallas Co)	101	99	10	2300	202	221	235	253	270	287
EASTERN DIVISION	Lufkin	98	96	15	2000	192	209	224	240	256	272
	Nacogdoches	98	96	15	2100	202	220	234	252	269	285
	Palestine	99	97	15	1900	182	207	212	228	243	258
	Crockett	99	97	15	2100	202	220	234	252	269	285
	Terrell	101	99	10	2850	250	273	292	313	334	355
	Tyler	99	97	15	2300	220	241	257	276	294	312
	Athens	100	98	15	2000	192	209	223	240	256	272
	*Centerville (Leon Co)	100	98	15	1900	182	202	212	228	243	258
	*Jacksonville (Cherokee Co.)	99	97	15	2000	192	209	223	240	256	272
	*Wills Point (Van Zandt Co)	100	98	10	2600	229	250	266	286	334	324
NORTHERN DIVISION	Decatur	101	99	10	2800	246	269	286	308	328	349
	Denison	101	99	10	2750	242	264	281	302	322	342
	Bonham	100	98	10	2700	238	259	276	297	317	336
	Gainesville	100	98	10	2400	211	230	246	264	281	299
	McKinney	100	98	10	2400	211	230	246	264	281	299
	Paris	100	98	10	2750	242	264	281	302	322	342
	Clarksville	100	98	10	2750	242	264	281	302	322	342
	Commerce	101	99	10	2850	250	273	292	313	334	355
	Sulphur Springs	101	99	10	2900	255	278	297	318	340	362
	Sherman	101	99	10	2500	220	240	266	275	293	312
	*Denton Exp Sta (Denton Co)	102	100	10	2350	207	225	240	259	276	293
SOUTHERN DIVISION	Brownwood	102	100	10	2450	224	244	260	279	298	317
	Stephenville	102	100	10	2550	224	245	261	280	299	318
	Corsicana	102	100	15	2450	235	256	274	294	314	332
	Hillsboro	101	100	15	2200	210	230	246	264	282	299
	Taylor	101	99	20	1950	206	224	240	257	275	292
	Cameron	101	99	20	1600	169	184	197	211	225	239
	Temple	101	99	20	1850	195	218	226	244	260	277
	Belton	100	98	20	2000	211	230	246	264	281	299
	McGregor	100	98	20	2000	211	230	246	264	281	299
	Killeen	100	99	20	2000	211	230	246	264	281	299
	Waco	101	99	20	2000	211	230	246	264	281	299
	*Whitney (Bosque Co)	101	99	15	2400	230	251	268	288	308	326

4 person residence
Infiltration - .75 Air Changes/hr.
Brick Veneer, R-13 Wall

Slab Floor
Ceiling - 6" (R-19) insulation under
Ventilated Attic - Light roof.
Duct - IN Attic with 2" insulation

WINDOW SCHEDULE				
MARK	TYPE	SIZE	MFG No.	MAT'L
A	RANCH WALL	9'-0" x 6'-1"	9061	ALUMN
B	"	4'-0" x 6'-1"	4061	"
C	SINGLE HUNG	3'-0" x 4'-5"	3045	"
D	" "	3'-0" x 3'-1"	3031	"
E	" "	2'-0" x 3'-1"	2031	"
F	HORIZ SLIDER	5'-11⅝" x 1'-11⅝"	6020 SV	"

DOORS	
MARK	SIZE
1	3'0" x 6'-8"
2	2'6" x 6'-8"
12	6'0" x 6'-8"



N
GARAGE AREA
BREAKFAST RM.
KITCHEN
FAMILY - DEN
DRESSING
BATH 1
POWDER
BED ROOM 1
HALL
DINING
LIVING ROOM
ENTRY
BED ROOM 2
BED ROOM 3
BATH 2
PORCH
PLANTER
A
B
C
D
E
F
1
2
12
30'-4½"
28'-10"
33'-0"
31'-1¼"
5'-0"
17'-10¾"
2'0"
4'0"

LAB: SYSTEM SIZING, DESIGN AND RETROFIT V-127

Lab 7: Analyze the DHW Load

One very important variable in sizing the array for a DHW system is the average water temperature available from the utility service. These monthly and annual averages may be used in the design process when locally specific temperatures are not available.

1. Call your water utility service company and record the monthly average water temperature.
2. Select a time, convenient to you and record the inlet water temperature at your residence. Let the cold water tap run for 2 to 3 minutes before measuring the temperature. Record at least 3 temperatures and average temperature.
3. Record the annual average water temperature, average water temperature for December, January and February.
4. Analyze the water temperature changes. What are the major factors accounting for these changes.
5. Compare the water temperature from the utility service company for the period you measured inlet water temperature at your residence. If there is a difference, why?

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 8: Collector Array Sizing - Short Form Method V-131

It is now time to begin the system sizing process. The first step is to analyze the hot water load (demand) space heat load and cooling load. Recommendations must be made as to what can be done to make the residence more energy efficient before solarization. Then the initial array size can be determined based upon pretty good assumptions. This preliminary calculation is very useful, particularly in the sales effort.

1. Use the data from Labs 6 and 7. Analyze the loads (space and hot water). Use patterns and structure.
2. Make recommendations as to improving energy efficiency in the structure and reducing total loads by changing use patterns.
3. Calculate the space heating, cooling and DHW loads again incorporating recommended changes.
4. Using the Collector short form work sheet with an assumed 75%, calculate the initial indicator array size.

COLLECTOR SIZING — SHORT FORM METHOD WORKSHEET

Line 1. Design Heat Loss of Structure (Btuh) .... ______ Btuh

Line 2. Winter Design Temperature Difference (°F) .... ______ °F

Line 3. Space Heat Load (Btu per degree-day):
(Line 1 ______) x 24 x .75
(Line 2 ______) = ... ______ Btu/D-day

Line 4. Approximate Solar Percentage of Total Load:
25%, 50% or 75% .... ______ %

Line 5. Approximate Total Collector Area (sq. ft.):
(Line 3 ______)
LC Factor ______ (from LC Factor Table) = ... ______ sq. ft.

Line 6. Effective Absorber Area Per Collector (from
Engineering Handbook Solar Collector sheet) .... ______ sq. ft.

Line 7. Estimated Number of Collectors:
(Line 5 ______)
(Line 6 ______) = ... ______

Line 8. Effective Area of Collector Array (sq. ft.):
(Line 6 ______) x (Line 7 ______) = ... ______ sq. ft.

LC FACTOR TABLE

CITY, STATE	LATITUDE	SOLAR PERCENTAGE OF TOTAL LOAD		
		25%	50%	75%
Ames, Ia.	42.0	134	46	19
Albuquerque, N.M.	35.0	334	120	60
Atlanta, Ga.	33.4	316	109	46
Boulder, Colo.	40.0	191	74	35
Columbus, Oh.	40.0	131	40	14
Dallas, Tx.	32.5	416	133	58
Davis, Ca.	38.3	394	120	46
Miami, Fl.	25.5	1443	646	382
Norfolk, Va.	36.5	270	90	40
San Diego, Ca.	38.3	394	120	46
Edmonton, At.	35.0	96	35	14
Moncton, N.B.	40.0	84	25	8
Toronto, Ot.	43.4	98	30	10
Vancouver, B.C.	48.6	102	28	8
Winnipeg, Ma.	49.5	94	33	13

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 9: Collector Array Sizing - Long Form Method V-135

The collector array sizing process continues, assuming the sale has been made. It is now time to get down to the business of making detailed, month by month load analyses and determining the solar fraction for each month. This will also be done for at least three different array sizes.

1. Use the initial array size selected for Lab 8 and proceed with the Long form worksheet. This method is a modified form of f-chart and does provide reasonable accuracy.
2. Following directions provided on sample forms, fill in all of the blank spaces in Worksheet I - Heat Load.
3. Fill in all the blank spaces in Worksheet II - Solar Percentage of Load.
4. If the resulting solar fraction, Line 14 of Worksheet II, is less than 60% or more than 80%, select a different array size that could be utilized and fill in blank spaces on Worksheet IIa, Line 15, 16 and 17.
5. Repeat step 4 until solar fraction falls as near 65% to 70% as is practical.
6. Of the three (or more) array sizes, which is the most cost effective for the application?
7. Select the placement for the array chosen and draw it in on the floor plan.

COLLECTOR SIZING — LONG FORM METHOD

WORKSHEET I. HEAT LOAD

Line 1. Design Heat Loss of Structure (Btuh) .... ____________ Btuh

Line 2. Winter Design Temperature Difference (°F)...................... ____________ °F

Line 3. Space Heat Load (Btu per degree-day):

$$\frac{(\text{Line 1 \_\_\_\_\_\_\_\_}) \times 24 \times .75}{(\text{Line 2 \_\_\_\_\_\_\_\_})} = \text{..............................} \text{ \_\_\_\_\_\_\_\_\_\_\_\_ Btu/D-day}$$

Line 4. Hot Water Temperature Difference (°F):
(Setpoint Temperature__________) –
(Cold Water Supply Temperature__________) = ... ____________ °F

Line 5. Hot Water Consumption (gal. per day) .... ____________ gal./day

Line 6. Hot Water Load (Btu per day):
(Line 4__________) x (Line 5 __________) x 8.33 = ... ____________ Btu/day

Column A		Column B	Column C	Column D	Column E
DAYS PER MONTH		HEATING DEGREE-DAYS (from Wea. & Rad. Tables)	SPACE HEAT LOAD (Btu/mo.): (Line 3) x (Column B) x (Abbreviation Factor*)	WATER HEAT LOAD (Btu/mo.): (Line 6) x (Column A) x (Abbreviation Factor*)	TOTAL HEAT LOAD (Btu/mo.): (Column C Abbreviation) + (Column D Abbreviation)
Jan.	31				
Feb.	28				
Mar.	31				
Apr.	30				
May	31				
June	30				
July	31				
Aug.	31				
Sept.	30				
Oct.	31				
Nov.	30				
Dec.	31				
TOTAL	365				

*The abbreviation factor abbreviates and rounds a large number by moving decimal six digits to the left; rounding to two decimal numbers; and multiplying by 10^6. (See Worksheet I Instructions for further explanation.)

COLLECTOR SIZING — LONG FORM METHOD

WORKSHEET II. SOLAR LOAD PERCENTAGE OF TOTAL LOAD

Line 7. Estimated Effective Absorber Area of Collector Array (from line 8 of COLLECTOR SIZING — SHORT FORM METHOD WORKSHEET) .... __________ sq. ft.

Line 8. Collector Performance Curve Slope (from Engineering Handbook data) .... __________

Line 9. Collector Peformance Curve Intercept (from Engineering Handbook data) .... __________

Line 10. Collector to Storage Heat Exchanger Factor (from Engineering Handbook data) .... __________

Line 11. Collector Orientation Factor (from Engineering Handbook data) .... __________

Line 12. Preliminary "X" Factor of F-Chart:
(Line 7__________) x (Line 8__________) x (Line 10__________) = .. __________

Line 13. Preliminary "Y" Factor of F-Chart:
(Line 7__________) x (Line 9__________) x (Line 10__________) x
(Line 11__________) = ... __________

Col. F	Col. G	Col. H	Col. I	Col. J	Col. K	Col. L	Col. M	Col. N
DAYS PER MONTH	HOURS PER MONTH	AVERAGE AMBIENT AIR TEMP. (°F): (from Wea. & Rad. Tables)	TEMP. FACTOR: 212-(Col. H)	"X" COORDINATE: (Line 12) x (Col. G) x (Col. I) x (Abbreviation Factor*) (Col. E, Worksheet I Abbreviation)	RADIATION ON TILTED SURFACE (from Wea. & Rad. Tables) Tilt ______° Azm. ______	"Y" COORDINATE: (Line 13) x (Col. F) x (Col. K) x (Abbreviation Factor*) (Col. E, Worksheet I Abbreviation)	SOLAR PERCENTAGE (from F-Chart)	SOLAR LOAD (Btu/mo.): (Col. E, Worksheet I Abbreviation) x (Col. M)
J-31	744							
F-28	696							
M-31	744							
A-30	720							
M-31	744							
J-30	720							
J-31	744							
A-31	744							
S-30	720							
O-31	744							
N-30	720							
D-31	744							
							YEARLY TOTAL	

Line 14. Yearly Solar Load Percentage:

$$\frac{(\text{Col. N. Abbreviation TOTAL }\_\_\_\_\_\_\_\_\_\_)}{(\text{Col. E, Worksheet I Abbreviation TOTAL }\_\_\_\_\_\_\_\_\_\_)} = \ldots\ldots\ldots\ldots \_\_\_\_\_\_\_\_\_\_ \%$$

The Abbreviation Factor abbreviates and rounds a large number by: moving decimal six digits to the left; rounding to two decimal numbers; and multiplying by 10^6. (See Worksheet I Instructions for further explanation.)

COLLECTOR SIZING — LONG FORM METHOD

WORKSHEET IIa. SOLAR LOAD PERCENTAGES FOR OTHER COLLECTOR AREAS

Line 15. Estimated Effective Absorber Area of Collector Array (sq. ft.) .... ________ sq. ft.

Line 16. Collector Area Factor:

(Line 15 ________)
(Line 7, Worksheet II ________) = ... ________

Col. O	Col. P	Col. Q	Col. R	Col. S
MONTH	"X" COORDINATE: (Line 16) x (Col. J, Worksheet II)	"Y" COORDINATE: (Line 16) x (Col. L, Worksheet II)	SOLAR PERCENTAGE (from F-Chart)	SOLAR LOAD (Btu/mo.): (Col. E, Worksheet I Abbreviation) x (Col. R)
Jan.				
Feb.				
Mar.				
April				
May				
June				
July				
Aug				
Sept				
Oct.				
Nov.				
Dec				
			YEARLY TOTAL	

Line 17. Yearly Solar Load Percentage:

(Col. S Abbreviation TOTAL ________)
(Col. E, Worksheet I Abbreviation TOTAL ________) = ... ________ %

Line 15. Estimated Effective Absorber Area of Collector Array (sq. ft.) .... ________ sq. ft.

Line 16. Collector Area Factor:

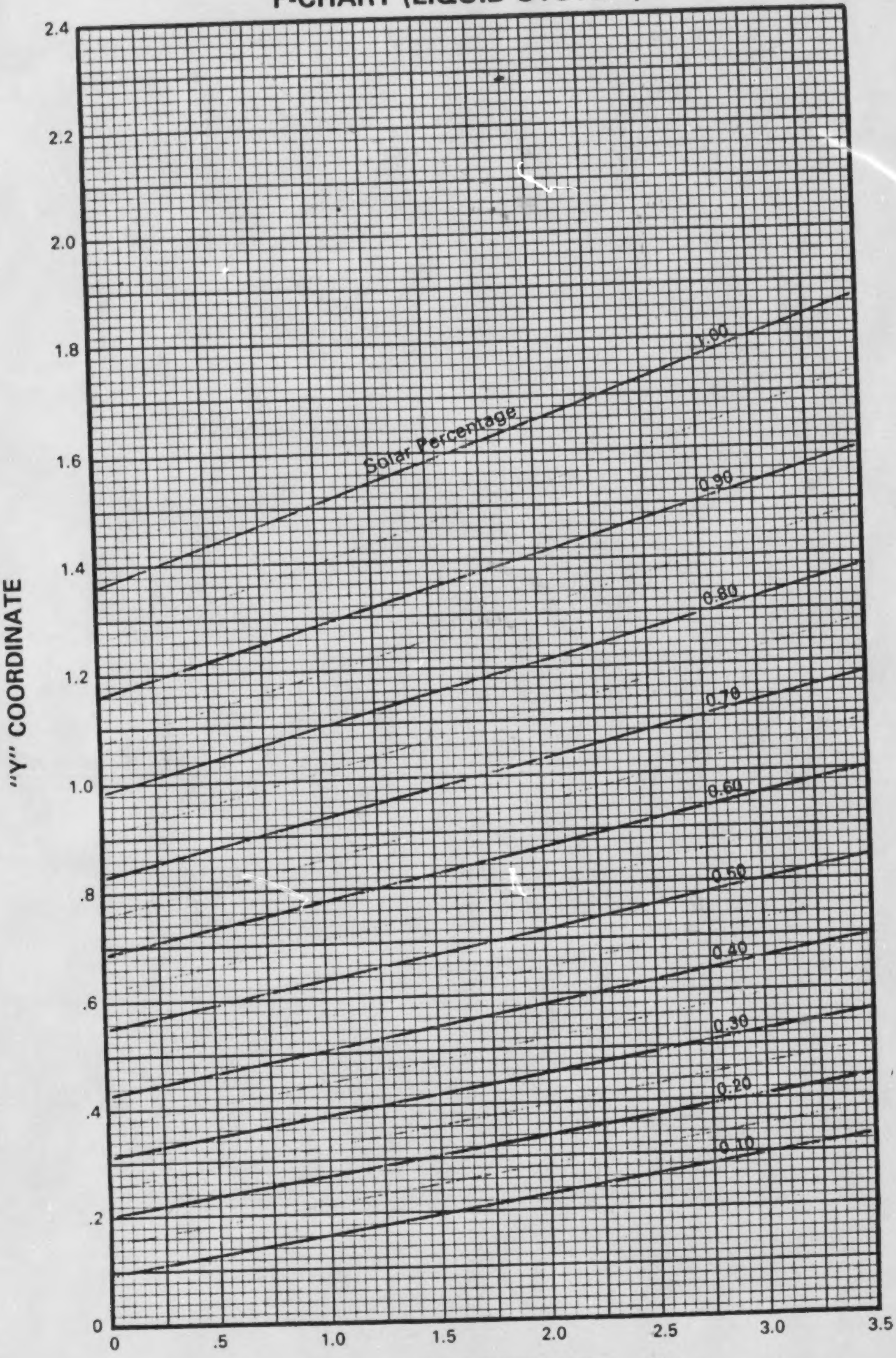
(Line 15 ________)
(Line 7, Worksheet II ________) = ... ________

Col. O	Col. P	Col. Q	Col. R	Col. S
MONTH	"X" COORDINATE: (Line 16) x (Col. J, Worksheet II)	"Y" COORDINATE: (Line 16) x (Col. L, Worksheet II)	SOLAR PERCENTAGE (from F-Chart)	SOLAR LOAD (Btu/mo.): (Col. E, Worksheet I Abbreviation) x (Col. R)
Jan				
Feb				
Mar				
April				
May				
June				
July				
Aug				
Sept				
Oct				
Nov				
Dec				
			YEARLY TOTAL	

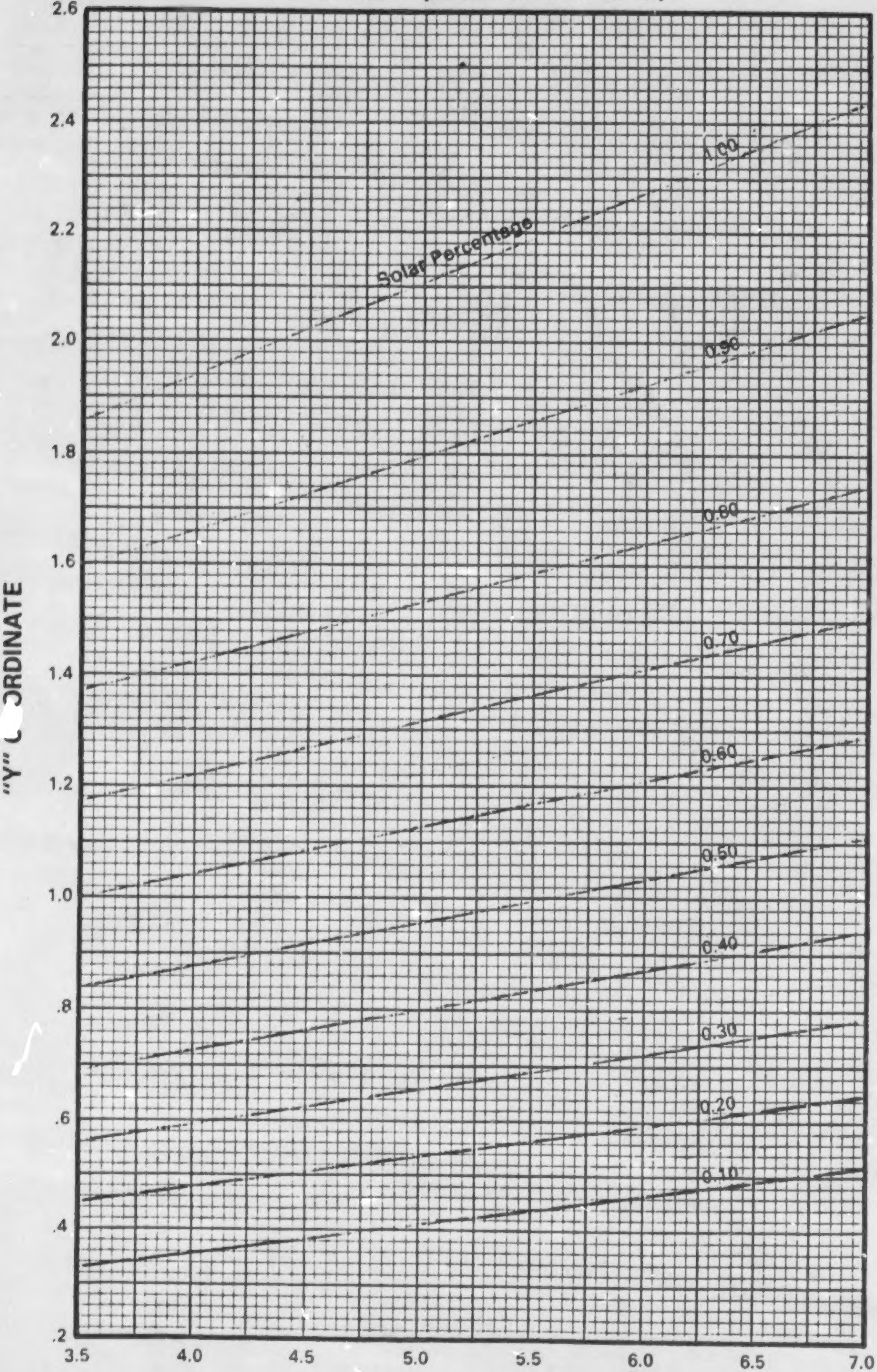
Line 17. **Yearly Solar Load Percentage:**

(Col. S Abbreviation TOTAL ________)
(Col. E, Worksheet I Abbreviation TOTAL ________) = ... ________ %

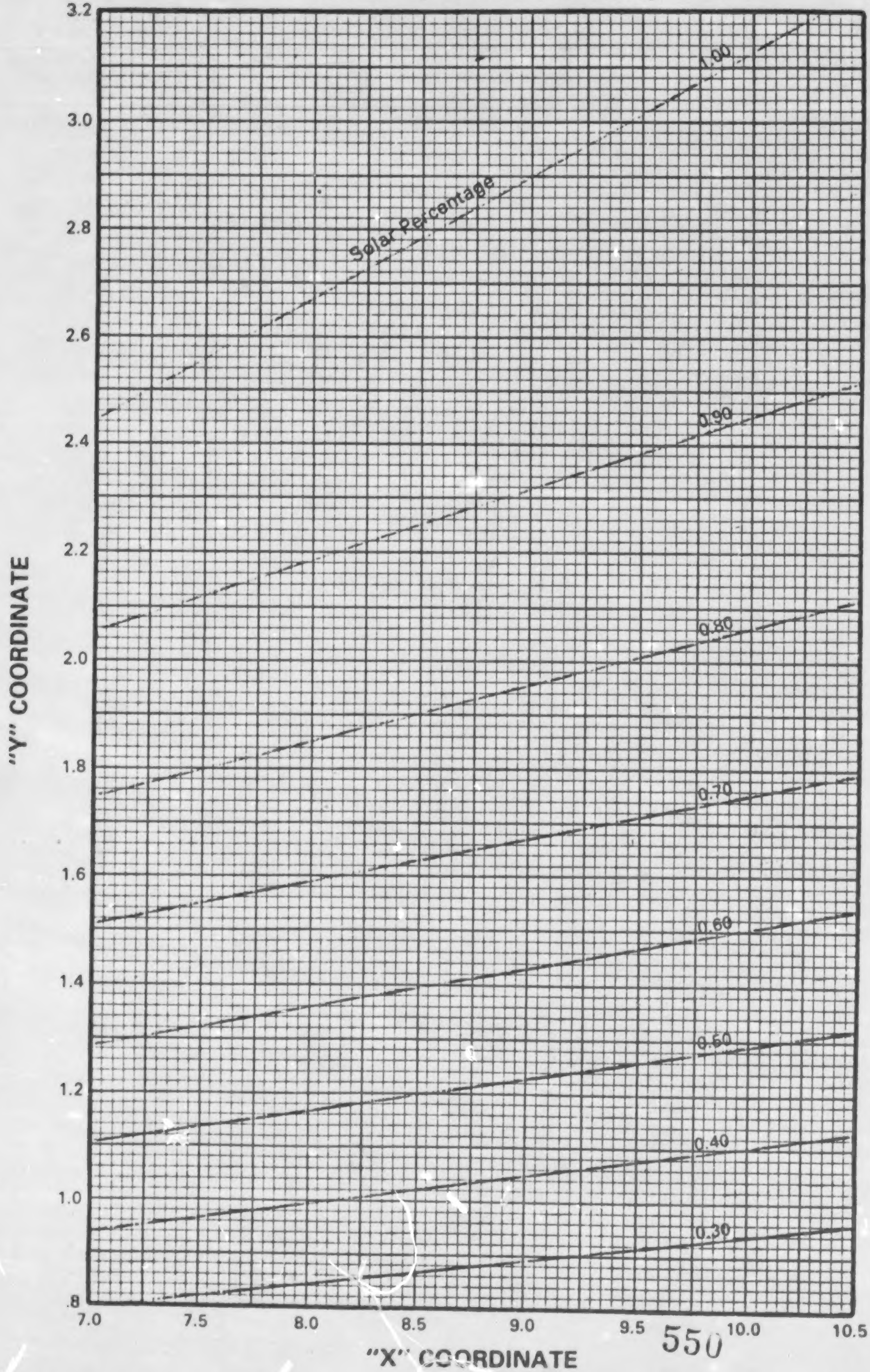
F-CHART (LIQUID SYSTEM)



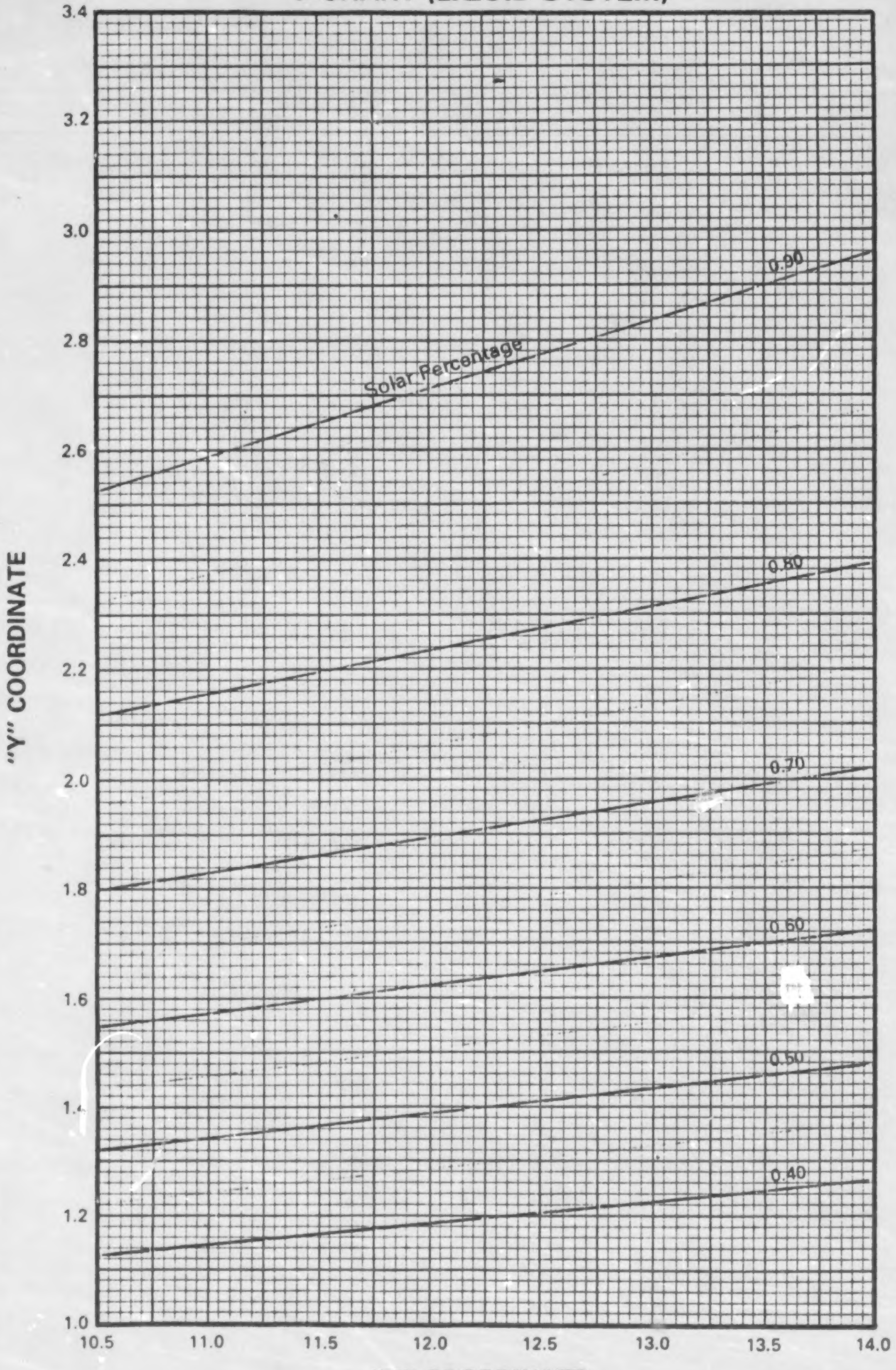
F-CHART (LIQUID SYSTEM)



F-CHART (LIQUID SYSTEM)



F-CHART (LIQUID SYSTEM)



COMPARING COLLECTOR CURVES

More than one collector may be plotted on a performance graph as illustrated by Figure 15. This provides for a direct performance comparison. For convenience, the intercepts and slopes of the two curves are listed on the graph. These may be referred to and used in the thermal calculations which will be discussed in the EQUIPMENT SELECTION section of this manual.

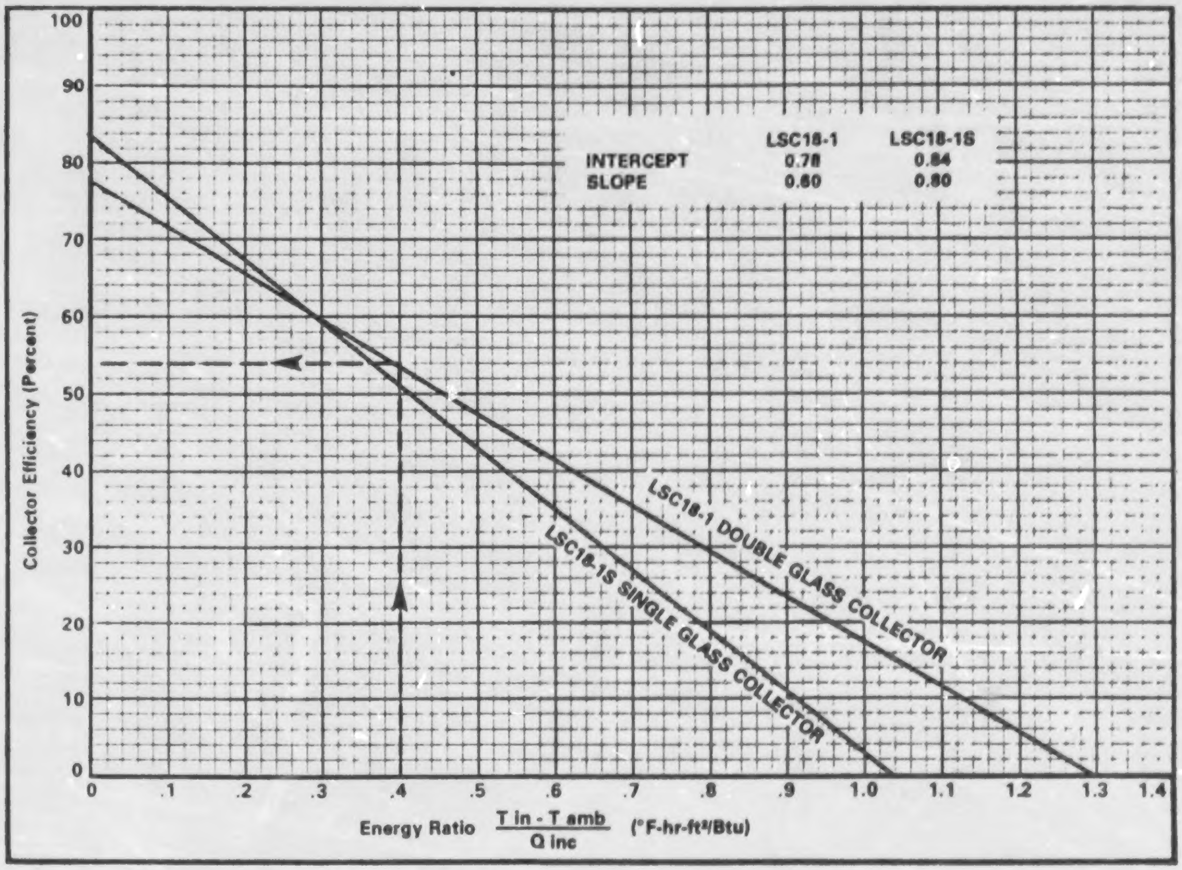


FIGURE 15 COMPARING COLLECTOR PERFORMANCE CHARTS

DETERMINING BTU CAPACITY OF COLLECTOR

The performance curve can be used to determine Btu capacity of a collector when the amount of available incident solar radiation (Q inc) is known. The Energy Ratio Scale formula (See Fig.15) is used. The available radiation in this example is 250 Btu/hr-ft².

Example Calculation

Assume there is a fluid inlet temperature (T in) of 110°F and an ambient temperature (T amb) of 10°F. Subtracting ambient temperature from inlet temperature results in a 100°F temperature difference. The temperature difference (100) divided by the solar radiation (250) equals .40. Refer to the collector peformance chart. Follow the example line from .40 of the bottom scale vertically to where it intersects the curve of the LSC18-1 Double Glass Collector. Read horizontally to the Collector Efficiency Scale from that point of intersection. This line indicates an efficiency of 54 percent. Thus, the collector is 54 percent efficient under the conditions used in the example. The Btu capacity of the collector in this instance would be 250 Btu/hr-ft² multiplied by 54 percent, or 135 Btu/hr-ft².

STEP 1.
COLLECTOR SIZING — SHORT FORM METHOD

INTRODUCTION

The short form method for collector sizing is the first step in the system designing process. Step 1A Worksheet employs an LC (Load-Collector) factor as the basis for estimating collector area. By using this short form, the designer can quickly estimate the collector area needed to achieve a certain solar percentage (25%, 50% and 75%) of the total space heat and domestic hot water load.

Approximate cost of the solar system can also be figured from the collector area estimate. This means that within minutes the designer can qualify the prospective buyer with respect to the prime factors of money and space.

NOTES: The short form method for collector sizing is only an estimation based on a number of assumptions, and should not be used in lieu of the long form method. Another short form means of estimating collector area employs an SA/L factor. However, Step 2 (collector sizing — long form) must be completed prior to initially using the SA/L method for a given area. The SA/L method is described on page 13 of this section.

STEP 1A. COLLECTOR SIZING — SHORT FORM METHOD WORKSHEET

Line 1. Design Heat Loss of Structure (Btuh):
(from standard heat loss calculation) .... 55,440 Btuh

Line 2. Winter Design Temperature Difference (°F):
(Indoor Design Temp. 70) – (Outdoor Design Temp. -10) = 80 °F

Line 3. Space Heat Load (Btu per degree-day):
(Line 1 55,440) x 24 x .75 / (Line 2 80) = ... 12,474 Btu/D-day

Line 4. Desired Annual Solar Percentage of Total Load:
25%, 50% or 75% .... 50 %

Line 5. Approximate Total Collector Area (sq. ft.):
(Line 3 12,474) / LC Factor 46 (from LC Factor Table for ______) = ... 271 sq. ft.

Line 6. Effective Absorber Area Per Collector (from
Engineering Handbook Solar Collector sheet) .... 15.4 sq. ft.

Line 7. Estimated Number of Collectors:
(Line 5 271) / (Line 6 15.4) = ... 17.6 OR 18 COLLECTORS

Line 8. Effective Area of Collector Array (sq. ft.):
(Line 6 15.4) x (Line 7 18) = ... 277 sq. ft.

LC FACTOR TABLE

CITY, STATE	LATITUDE	SOLAR PERCENTAGE OF TOTAL LOAD		
		25%	50%	75%
Ames, Ia.	42.0	134	46	19
Albuquerque, N.M.	35.0	334	120	60
Atlanta, Ga.	33.4	316	109	46
Boulder, Colo.	40.0	191	74	35
Columbus, Oh.	40.0	131	40	14
Dallas, Tx.	32.5	416	133	58
Davis, Ca.	38.3	394	120	46
Miami, Fl.	25.5	1443	646	382
Norfolk, Va.	36.5	270	90	40
San Diego, Ca.	32.4	459	211	112
Edmonton, At.	53.3	96	35	14
Moncton, N.B.	40.0	84	25	8
Toronto, Ot.	43.4	98	30	10
Vancouver, B.C.	48.6	102	28	8
Winnipeg, Ma.	49.5	94	33	13

INSTRUCTIONS FOR STEP 1A WORKSHEET

Line 1. Industry-approved procedures should be followed to calculate design heat loss, such as outlined in *NESCA* Load Calculation Manual J* or *ASHRAE* Fundamentals Guide*. (See sample summary sheet of *NESCA Manual J Worksheet* on page 5 of this section.)

NOTE: Heat loss calculation procedures are the same for a "solar" residence as a "non-solar" residence.

Line 2. Winter Design Temp. Difference = Indoor Design Temp. – Outdoor Design Temp. **NOTE**: Outdoor winter design temp. (°F) is listed on the Weather and Radiation Tables for 15 sites in the DATA portion of this section. Indoor design temp. is determined by the system designer and/or homeowner.

Line 3. Calculate space heat load in Btu per degree-day:

$$\frac{(\text{Line 1}) \times \overset{\text{ⓐ}}{24} \times \overset{\text{ⓑ}}{.75}}{(\text{Line 2})}$$

ⓐ 24 stands for number of hours per day. This step converts heat loss from Btu per hour to Btu per day.

ⓑ .75 is a proportionality factor. This factor modifies heat loss calculations to take into consideration current construction practices (i.e. increased insulation) which reduce heat loss.

NOTE: Degree-day is a unit of measurement for determining energy use. For further information see Step 2A Worksheet Instructions.

Line 4. Select one of the following solar percentages of total load:

25%, 50% or 75%

NOTE: The designer and/or homeowner must choose one of the above solar load percentages in order to select the proper LC factor in Line 5. The optimum solar load percentage in terms of economic payback is usually between 50% and 75%.

Line 5. Calculate approximate total collector area for desired solar load percentage:

$$\frac{(\text{Line 3})}{\text{LC factor (from LC Factor Table)}}$$

NOTE: Find appropriate LC (Load Collector) factor from LC Table on worksheet. LC factor is ratio between the building load and the collector area needed to obtain a certain solar percentage of that load.

Line 6. Effective absorber area per Lennox collector can be found in Engineering Handbook Collector sheet. (This sheet is in DATA portion of this section.) Effective area of both the Lennox LSC18-1 double glass collector and the Lennox LSC18-1S single glass collector is 15.4 sq. ft.

Line 7. Calculate estimated number of collectors:

$$\frac{(\text{Line 5})}{(\text{Line 6})}$$

Line 8. Calculate effective absorber area of collector array (sq. ft.):

(Line 6) x (Line 7)

**NESCA stands for National Environmental Systems Contractors Association. ASHRAE stands for American Society of Heating, Refrigeration and Air Conditioning Engineers.*

STEP 2.
COLLECTOR SIZING — LONG FORM METHOD

INTRODUCTION

The long form method for collector sizing is used after the designer has qualified the buyer with the short form. The long form provides more accurate collector performance documentation than the short form. Such documentation is normally required by banks, lending institutions or funding agencies (i.e. HUD, FHA).

Included in the long form are monthly and yearly breakdowns of heat load and solar percentages of the total heat load. These breakdowns are based on several estimated collector areas. The designer and buyer are able to compare the merits of the various collector areas and choose that area which best suits their needs.

Three worksheets comprise the long form:

Step 2A Worksheet figures monthly and yearly heat loads for space heat and domestic hot water;

Step 2B Worksheet figures monthly and yearly solar load percentages, based on collector area estimate from short form;

Step 2C Worksheet is an abbreviated version of Step 2B Worksheet. If the designer desires additional monthly and yearly solar load percentage input for other collector areas, the worksheet provides a quick way to figure this.

COLLECTOR SIZING — LONG FORM METHOD

STEP 2A. HEAT LOAD WORKSHEET

(Instructions for this worksheet on next page.)

Line 1. Design Heat Loss of Structure (Btuh) .... 55,440 Btuh
(from standard heat loss calculation)

Line 2. Winter Design Temperature Difference (°F):
(Indoor Design Temp. 70) - (Outdoor Design Temp. -10) = .. 80 °F

Line 3. Space Heat Load (Btu per degree-day):

$$\frac{(\text{Line 1 } 55{,}440) \times 24 \times .75}{(\text{Line 2 } 80)} = \ldots\ldots\ldots\ldots\ 12{,}474 \text{ Btu/D-day}$$

Line 4. Hot Water Temperature Difference (°F):
(Setpoint Temperature 140°F) –
(Cold Water Supply Temperature 55°F) = ... 85 °F

Line 5. Hot Water Consumption (gal. per day) .... 80 gal./day

Line 6. Hot Water Load (Btu per day):
(Line 4 85) x (Line 5 80) x 8.33 = ... 56,644 Btu/day

Column A		Column B	Column C	Column D	Column E
DAYS PER MONTH		HEATING DEGREE-DAYS (from Wea. & Rad.Tables for____)	SPACE HEAT LOAD (Btu/mo.): (Line 3) x (Column B) x (Abbreviation Factor*)	WATER HEAT LOAD (Btu/mo.): (Line 6) x (Column A) x (Abbreviation Factor*)	TOTAL HEAT LOAD (Btu/mo.): (Column C Abbreviation) + (Column D Abbreviation)
Jan.	31	1429	17.83 x 10^6	1.76 x 10^6	19.59 x 10^6
Feb.	28	1151	14.36 " "	1.59 " "	15.95 " "
Mar.	31	970	12.10 " "	1.76 " "	13.86 " "
Apr.	30	468	5.84 " "	1.70 " "	7.54 " "
May	31	191	2.38 " "	1.76 " "	4.14 " "
June	30	32	0.40 " "	1.70 " "	2.10 " "
July	31	0	0.00	1.76 " "	1.76 " "
Aug.	31	15	0.19 " "	1.76 " "	1.95 " "
Sept.	30	105	1.31 " "	1.70 " "	3.01 " "
Oct.	31	370	4.62 " "	1.76 " "	6.38 " "
Nov.	30	834	10.40 " "	1.70 " "	12.10 " "
Dec.	31	1259	15.70 " "	1.76 " "	17.46 " "
TOTAL	365	6824	85.13 " "	20.71 " "	105.84 " "

**The abbreviation factor abbreviates and rounds a large number by moving decimal six digits to the left; rounding to two decimal numbers; and multiplying by 10^6. (See Step 2A Worksheet Instructions for further explanation.)*

INSTRUCTIONS FOR STEP 2A WORKSHEET

Lines 1-3 These lines are identical to lines 1-3 of STEP 1A Worksheet. See Step 1A Worksheet Instruction for explanation.

Line 4. Determine hot water temperature difference:

ⓐ (Water Heater Setpoint Temperature) —

ⓑ (Cold Water Supply Temperature)

ⓐ Water heater setpoint temperature is selected by homeowner; 120°-140°F is normal setpoint.

ⓑ Cold water supply temperature is temperature of water entering house; consult local water department or take temperature reading from cold water tap.

Line 5. Determine daily hot water consumption. If exact consumption is not known, a rule of thumb is 20 gallons per each family member.

Line 6. Calculate hot water load in Btu per day: (Line 4) x (Line 5) x 8.33

NOTE: 8.33 converts gallons to pounds so that heat load in Btu can be figured. 8.33 lb. = 1 gal. of water.

Col. B. Find heating degree-days for solar home locale from WEATHER AND RADIATION TABLES. Tables for 15 sites are in DATA portion of this section.

NOTE: A degree-day is a unit of measure used in determining energy usage for space heating. A degree-day for heating is based on two assumptions: 1) Over a long period of time, passive solar and internal heat gains will offset the heat loss of a residence when the mean daily outdoor temperature is 65°F; and 2) The heat load will be proportional to the difference between 65°F and the mean daily temperature.

Degree-days for heating are figured by subtracting mean daily temperature from 65°F. If the mean temperature for a certain day is 55°F, there are 10 degree-days for that day (65°-55° = 10 degree-days). If the mean temperature for that day is 65°F or above there are 0 degree-days.

Col. C, D, E. Complete the table by filling in these columns as directed on worksheet.

NOTE: Columns C, D and E contain an Abbreviation Factor. The Abbreviation Factor abbreviates and rounds a large number to a smaller, more workable number. This is done by moving the decimal six digits to the left, rounding to two decimal numbers and multiplying by 10^6 ($10^6 = 1{,}000{,}000$). **Example:** In Column C for the month of January, assume multiplying Line 3 by Column B yields 19,014,274. Using the Abbreviation Factor 19,014,274 becomes 19.01×10^6.

COLLECTOR SIZING — LONG FORM METHOD

STEP 2B. SOLAR LOAD PERCENTAGE OF TOTAL LOAD WORKSHEET

(Instructions for this worksheet on next page.)

Line 7. Estimated Effective Absorber Area of Collector Array (from line 8 of Step 1A Worksheet or SA/L Short Form Worksheet .... 277 sq. ft.

Line 8. Collector Performance Curve Slope (from Engineering Handbook data) .... .60

Line 9. Collector Peformance Curve Intercept (from Engineering Handbook data) .... .78

Line 10. Collector to Storage Heat Exchanger Factor (.95 is factor for Lennox systems).......... .95

Line 11. Collector Orientation Factor (.95 is factor for Lennox systems).......... .95

Line 12. Preliminary "X" Factor of F-Chart: (Line 7 277) x (Line 8 .60) x (Line 10 .95) = .. 157.89

Line 13. Preliminary "Y" Factor of F-Chart: (Line 7 277) x (Line 9 .78) x (Line 10 .95) x (Line 11 .95) = ... 194.99

Col. F	Col. G	Col. H	Col. I	Col. J	Col. K	Col. L	Col. M	Col. N
DAYS PER MONTH	HOURS PER MONTH	AVERAGE AMBIENT AIR TEMP. (°F): (from Wea. & Rad. Tables)	TEMP. FACTOR: 212-(Col. H)	"X" COORDINATE: (Line 12) x (Col. G) x (Col. I) x (Abbreviation factor*) (Col. E, Step 2A Worksheet Abbreviation)	RADIATION ON TILTED SURFACE (from Wea. & Rad. Tables) Tilt 50° Azm. 0	"Y" COORDINATE: (Line 13) x (Col. F) x (Col. K) x (Abbreviation Factor*) (Col. E, Step 2A Worksheet Abbreviation)	SOLAR PERCENTAGE (from F-Chart)	SOLAR LOAD (Btu/mo.): (Col. E, Step 2A Worksheet Abbreviation) x (Col. M)
J-31	744	19	193	1.16	1283	.40	.31	6.07×10^6
F-28	696	25	187	1.29	1509	.52	.39	6.22 " "
M-31	744	32	180	1.33	1506	.66	.49	6.79 " "
A-30	720	48	164	2.47	1469	1.14	.73	5.50 " "
M-31	744	59	153	4.34	1501	2.19	1.00	4.14 " "
J-30	720	68	144	7.80	1576	4.39	1.00	2.10 " "
J-31	744	73	139	9.28	1609	5.52	1.00	1.76 " "
A-31	744	72	140	8.43	1572	4.87	1.00	1.95 " "
S-30	720	63	149	5.44	1541	2.99	1.00	3.01 " "
O-31	744	52	160	2.94	1495	1.41	.85	5.42 "
N-30	720	36	176	1.65	1290	.62	.48	5.81 " "
D-31	744	25	187	1.26	1095	.38	.29	5.06 " "
							YEARLY TOTAL	53.83 " "

Line 14. Yearly Solar Load Percentage:

$$\frac{\text{(Col. N. Abbreviation TOTAL } 53.83 \times 10^6\text{)}}{\text{(Col. E, Step 2A Worksheet Abbreviation TOTAL } 5.84 \times 10^6\text{)}} = \ldots\ldots\ldots\ldots\ 50.8\ \%$$

The Abbreviation Factor abbreviates and rounds a large number by: moving decimal six digits to the left; rounding to two decimal numbers; and multiplying by 10^6. (See Step 2A Worksheet Instruction for further explanation.)

INSTRUCTIONS FOR STEP 2B WORKSHEET

Line 7. Enter the approximate collector area desired as calculated in either Line 8 of the Step 1A Worksheet or the SA/L Short Form Worksheet.

Line 8. Determine collector performance curve slope from Lennox Engineering Handbook Solar Collector sheet (in DATA portion of this section). (See "Slope and Inercept" portion of SOLAR ENERGY COLLECTION section for further explanation.)
NOTE: Slope for Lennox LSC18-1 double glass collector is .60:

$$\frac{\text{"Y" axis intercept}}{\text{"X" axis intercept}} = \frac{.78}{1.3} = .60$$

Slope for Lennox LSC18-1S single glass collector is .81:

$$\frac{\text{"Y" axis intercept}}{\text{"X" axis intercept}} = \frac{.84}{1.04} = .81$$

Line 9. Find "Y" axis intercept of collector performance curve from Engineering Handbook Solar Collector sheet (in DATA portion of this section).
NOTE: Intercept of Lennox LSC18-1 collector performance curve is .78; LSC18-1S intercept is .84. (See "Slope and Intercept" portion of SOLAR ENERGY COLLECTION section for further explanation.)

Line 10. Find collector to storage heat exchanger factor.
NOTE: This factor for Lennox equipment is .95.

Line 11. Find collector orientation factor.
NOTE: This factor for Lennox Collectors is .95.

Line 12. Calculate preliminary "X" factor of F-Chart:
(Line 7) x (Line 8) x (Line 10)
NOTE: F-Charts are graphs used to determine solar percentage of total load and are located in the DATA portion (Tables 2a-2d) of this section.
The F-Charts are the result of correlating hundreds of detailed simulations of solar heating systems. For standard system configurations, the F-Charts eliminate the need for detailed simulations using hourly meteorological data.

Line 13. Calculate preliminary "Y" factor of F-Chart.
(Line 7) x (Line 9) x (Line 10) x (Line 11)

Col. H. Enter monthly average ambient temperatures for appropriate location from WEATHER AND RADIATION TABLES (tables for 15 sites are in DATA portion of this section).

Col. I. Calculate average ambient air temperature factor for each month:
212 — (Col. H)
NOTE: 212 is simply a reference number, and has no other significance.

Col. J. Calculate "X" coordinate of F-Chart for each month.:

$$\frac{\text{(Line 12) x (Col. G) x (Col. I) x (Abbrev. Fac.)}}{\text{(Col. E, Step 2A Worksheet Abbrev.)}}$$

NOTE: The Abbreviation Factor is the same as used in Step 2A Worksheet. (See Step 2A Worksheet Instructions for further explanation.)
NOTE: The 10^6 factor in numerator and denominator cancel, leaving a simple division calculation. **Example:** Assume for the month of January the numerator is figured to be 23.65×10^6 and the denominator 20.77×10^6. The two 10^6 factors cancel, and 23.65 divided by 20.77 yields 1.14.

$$\frac{23.65}{20.77} = 1.14$$

Col. K. Enter selected collector tilt and azimuth angles at top of graph, then enter the appropriate average daily radiation values for the selected location from WEATHER AND RADIATION TABLES (tables for 15 sites are in DATA portion of this section).
NOTE: Review THE SUN section for further explanation on how to select collector tilt and azimuth angles.

Col. L. Calculate "Y" coordinate of F-Chart for each month:

$$\frac{\text{(Line 13) x (Col. F) x (Col. K) x (Abbrev. Fac.)}}{\text{(Col. E., Step 2A Worksheet Abbrev.)}}$$

NOTE: The Abbreviation Factor is the same as used in Step 2A Worksheet. (See Step 2A Worksheet Instructions for further explanation.)

Col. M. Plot "X" coordinate (Column J), and "Y" coordinate (Column L) on appropriate F-Chart and enter monthly percentage of total load carried by solar. (F-Charts in DATA portion of this section.)

Col. N. Calculate solar load (monthly and yearly) in Btu:
(Col. E, Step 2A Worksheet Abbrev.) x (Col. M)

Line 14. Calculate yearly percentage of total load carried by solar:

$$\frac{\text{(Col. N. Abbreviation TOTAL)}}{\text{(Col. E, Step 2A Worksheet Abbrev. TOTAL)}}$$

COLLECTOR SIZING — LONG FORM METHOD

STEP 2C. SOLAR LOAD PERCENTAGES FOR OTHER COLLECTOR AREAS WORKSHEET

(Instructions for worksheet on next page.)

Line 15. Estimated Effective Absorber Area of Collector Array (sq. ft.) .... 215.6 sq. ft.
(14 COLLECTORS)

Line 16. Collector Area Factor:
(Line 15 215.6)
(Line 7, Step 2B Worksheet 277) = ... .78

Col. O	Col. P	Col. Q	Col. R	Col. S
MONTH	"X" COORDINATE: (Line 16) x (Col. J, Step 2B Worksheet)	"Y" COORDINATE: (Line 16) x (Col. L, Step 2B Worksheet)	SOLAR PERCENTAGE (from F-Chart)	SOLAR LOAD (Btu/mo.): (Col. E, Step 2A Worksheet Abbreviation) x (Col. R)
Jan.	.90	.31	.24	4.70×10^6
Feb.	1.01	.41	.32	5.10 " "
Mar	1.19	.51	.39	5.41 " "
April	1.93	.90	.62	4.67 " "
May	3.39	1.71	.95	3.93 " "
June	6.08	3.42	1.00	2.10 " "
July	7.24	4.31	1.00	1.76 " "
Aug.	6.58	3.80	1.00	1.95 " "
Sept.	4.24	2.33	1.00	3.01 " "
Oct.	2.29	1.10	.72	4.59 " "
Nov.	1.28	.48	.39	4.72 " "
Dec.	.98	.30	.22	3.84 " "
			YEARLY TOTAL	45.78 " "

Line 17. Yearly Solar Load Percentage:
(Col. S Abbreviation TOTAL 45.78×10^6)
(Col. E, Step 2A Worksheet Abbreviation TOTAL 10584×10^6) = ... 43.25 %

Line 15. Estimated Effective Absorber Area of Collector Array (sq. ft.) .... 338.8 sq. ft.
(22 COLLECTORS)

Line 16. Collector Area Factor:
(Line 15 338.8)
(Line 7, Step 2B Worksheet 277) = ... 1.22

Col. O	Col. P	Col. Q	Col. R	Col. S
MONTH	"X" COORDINATE: (Line 16) x (Col. J, Step 2B Worksheet)	"Y" COORDINATE: (Line 16) x (Col. L, Step 2B Worksheet)	SOLAR PERCENTAGE (from F-Chart)	SOLAR LOAD (Btu/mo.): (Col. E, Step 2A Worksheet Abbreviation) x (Col. R)
Jan.	1.42	.49	.36	7.05×10^6
Feb	1.57	.63	.47	7.50 " "
Mar.	1.87	.81	.57	7.90 " "
April	3.01	1.39	.84	6.33 " "
May	5.29	2.67	1.00	4.14 " "
June	9.52	5.36	1.00	2.10 " "
July	11.32	6.73	1.00	1.76 " "
Aug.	10.28	5.94	1.00	1.95 " "
Sept.	6.64	3.65	1.00	3.01 " "
Oct.	3.59	1.72	.94	6.00 " "
Nov.	2.01	.76	.56	6.78 " "
Dec.	1.54	.46	.34	5.94 " "
			YEARLY TOTAL	60.46 " "

Line 17. Yearly Solar Load Percentage:
(Col. S Abbreviation TOTAL 60.46×10^6)
(Col. E, Step 2A Worksheet Abbreviation TOTAL 105.84×10^6) = ... 57.1 %

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 10: Storage Sizing

Once the array size has been determined, it is necessary to size the storage. A rule of thumb for storage sizing that has proven effective is: 1-2 gallon / ft^2 of collector array for liquid systems and 50-100 lbs. of rock/ft^2 for air systems. Storage for 1 1/2-2 days is usually required.

Using the appropriate "rule of thumb" from above:

1. Determine the storage size required.
2. Using the floor plan from Lab 6, indicate where the storage unit would be located.
3. If a liquid system is used, draw a sketch of the tank (vertical or horizontal).
4. Make a decision on which type and how much insulation will be used for storage unit.

Lab 11: Heat Exchangers

Once the collector array and storage requirements have been determined, the heat exchanger must be selected. The heat exchanger is a vital link in the system.

Using the example heat exchanger worksheet and manufacturing spec sheets provided by the lab attendant:

1. Determine the approach temperature.
2. Select a heat-exchanger for
    a. Series, counterflow
    b. Parallel, counterflow
3. Make a decision as to which arrangement (A or B above) will be used and justify your decision in writing.
4. Select heat-exchanger(s) model number.

HEAT EXCHANGER

Introduction

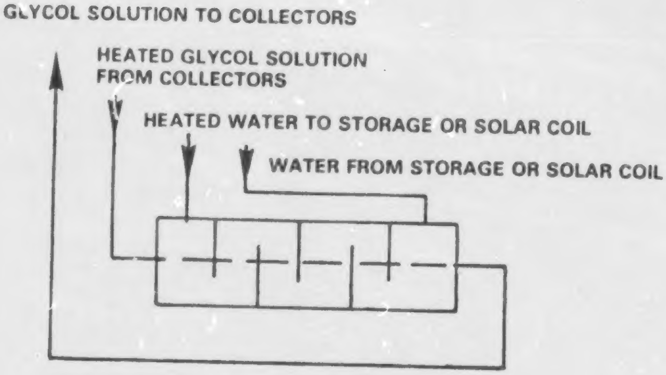
The components in this step are sized according to the number of collectors (or effective sq. ft.) of the collector array.

Sizing the heat exchanger can be especially complex. A table has been developed for a stated set of conditions that alleviates this complexity. The following information is intended to give the student a brief insight into some of the terms and principles involved in sizing a heat exchanger and developing the selection table.

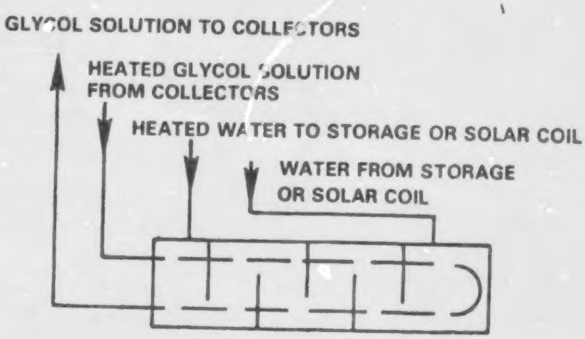
Background Information For Heat Exchanger Sizing

The heat exchanger is sized according to the amount of surface area needed to most efficiently transfer collector loop heat to the remaining system loops on the opposite side of the heat exchanger. A "trade-off" exists between the solar collector area and the proper heat exchanger surface area. To explain, for the same Btu/hr. solar heat input into storage, an undersized heat exchanger will require a much larger collector surface area as compared with an adequately sized heat exchanger. Since collector surface area is more costly to attain in comparison with the heat exchanger surface area, the trade-off should be towards generous sizing of the exchanger. This is in order to maintain collection efficiency (reduced collector area for equal solar heat input into storage).

Two basic types of ethylene glycol to water heat exchanger units are described below.


GLYCOL SOLUTION TO COLLECTORS
HEATED GLYCOL SOLUTION FROM COLLECTORS
HEATED WATER TO STORAGE OR SOLAR COIL
WATER FROM STORAGE OR SOLAR COIL

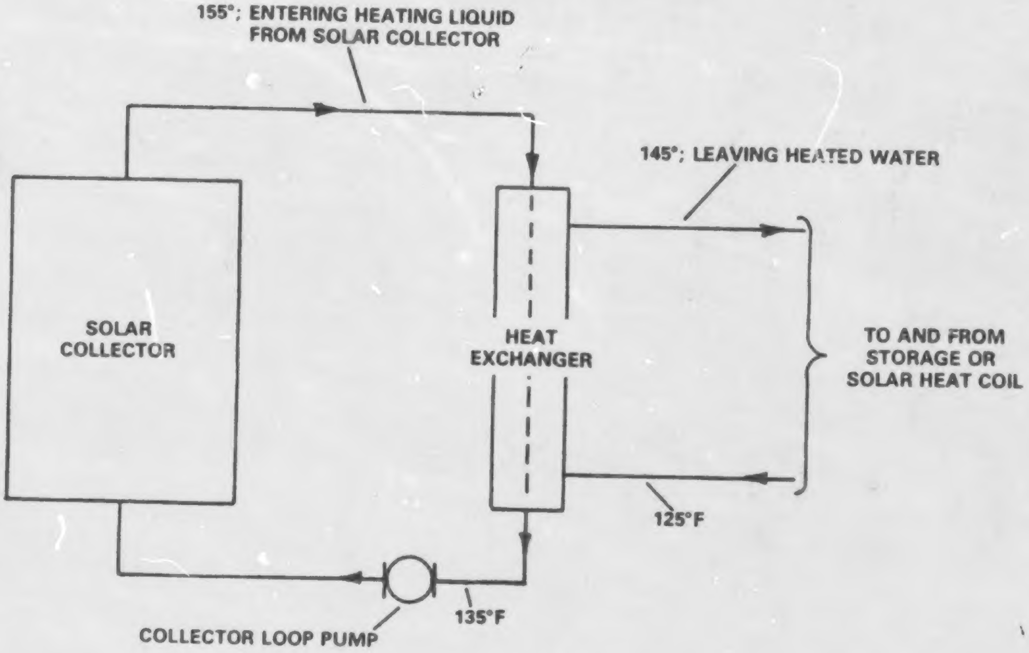
COUNTERFLOW STRAIGHT TUBE HEAT EXCHANGER


GLYCOL SOLUTION TO COLLECTORS
HEATED GLYCOL SOLUTION FROM COLLECTORS
HEATED WATER TO STORAGE OR SOLAR COIL
WATER FROM STORAGE OR SOLAR COIL

"U" TUBE HEAT EXCHANGER

The counterflow straight tube heat exchanger will be used to describe approach temperature difference, as this factor influences heat exchanger sizing and consequent collector operating efficiency.

Approach temperature difference for a heat exchanger is the difference in temperature between the incoming **heating** fluid and the leaving **heated** fluid. The figure below illustrates approach temperature difference (△T) for a glycol to water solar heat exchanger. The exchanger is designed for 10° "approach".

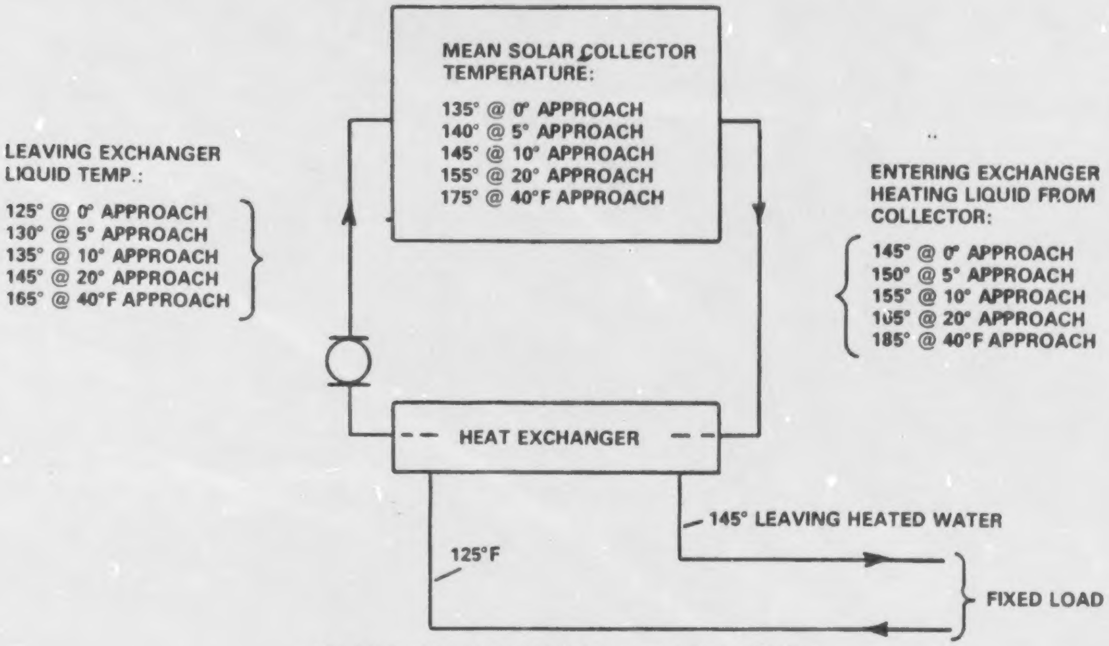

155°; ENTERING HEATING LIQUID FROM SOLAR COLLECTOR
145°; LEAVING HEATED WATER
SOLAR COLLECTOR
HEAT EXCHANGER
TO AND FROM STORAGE OR SOLAR HEAT COIL
125°F
135°F
COLLECTOR LOOP PUMP

HEAT EXCHANGER DESIGNED FOR 10° APPROACH; (155° - 145° = 10°)

The approach △T used for design of the heat exchanger has great significance for glycol solution collector systems. This is because of its effect on required collector temperature to meet a stated heat exchanger load. The higher the design approach △T, the higher the required mean collector liquid temperature to meet the load.

The following figure illustrates the effect of heat exchanger design approach △T on required solar collector liquid temperatures for a fixed load.

The following figure illustrates the effect of heat exchanger design approach △T on required collector liquid temperatures for a fixed load.


MEAN SOLAR COLLECTOR TEMPERATURE:
135° @ 0° APPROACH
140° @ 5° APPROACH
145° @ 10° APPROACH
155° @ 20° APPROACH
175° @ 40°F APPROACH
LEAVING EXCHANGER LIQUID TEMP.:
125° @ 0° APPROACH
130° @ 5° APPROACH
135° @ 10° APPROACH
145° @ 20° APPROACH
165° @ 40°F APPROACH
ENTERING EXCHANGER HEATING LIQUID FROM COLLECTOR:
145° @ 0° APPROACH
150° @ 5° APPROACH
155° @ 10° APPROACH
165° @ 20° APPROACH
185° @ 40°F APPROACH
HEAT EXCHANGER
145° LEAVING HEATED WATER
125°F
FIXED LOAD

CHANGE IN MEAN LIQUID TEMPERATURE IN SOLAR COLLECTORS WITH CHANGE IN HEAT EXCHANGER DESIGN APPROACH △T

The increase in mean solar panel temperature with increased heat exchanger approach temperatures will affect collection efficiency as follows for a typical collector at a 40° outdoor temperature.

Heat Exchanger Approach △T °F	Mean Collector Temp., °F	Outdoor Ambient °F	△T; Mean Collector Minus Outdoor °F	Collector Efficiency @250 B/H/FT² Insol.
0° (base)	135	40	95	35%
5°	140	40	100	33.5%
10°	145	40	105	32%
20°	155	40	115	29%
40°	175	40	135	24%

The glycol to water heat exchanger used in solar systems should be base sized for a 5 to 15° approach. The reason is that exchangers sized to less than a 5° approach will provide very little increased collector performance for a comparatively large increase in exchanger size and cost. Heat exchangers sized for over a 15° approach will reduce collector performance excessively relative to the decreased cost of the exchanger.

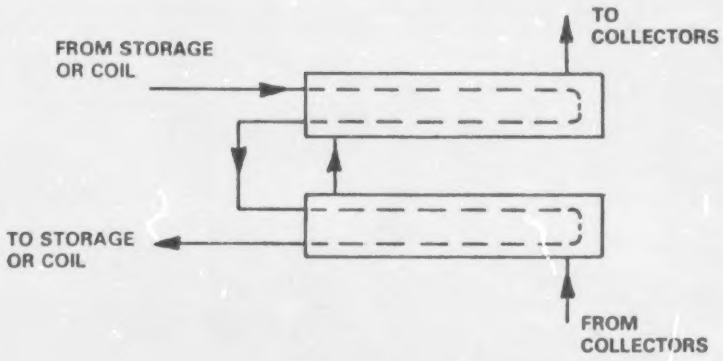
It should be noted that approach △T is a rough comparative measure of heat exchanger size. A heat exchanger selected for a 40° approach will be about 1/4 the size of an exchanger selected for a 10° approach. The difference in cost will generally not be proportionate. Considering the relatively high installed cost of the solar collectors, it would be unwise to sacrifice collector performance in order to save a little money on a smaller sized heat exchanger.

Logarithmic (Log) Mean Temperature Difference (LMTD) and *Effectiveness* are additional terms encountered when sizing heat exchangers. (A logarithm is a mathematical proportion normally used to shorten calculations.)

The rate of heat transfer between the shell and tube of the exchanger is influenced by the temperature difference of the fluids. The greater the temperature difference, the greater the rate and amount of heat transfer. This relationship varies logarithmically, hence LMTD.

Effectiveness is the ratio of the actual rate of heat transfer between the shell and tube to the maximum rate of heat transfer between the shell and tube if the tube bundle had an infinite surface area. A heat exchanger for a solar system should have an Effectiveness of 0.6 or greater.

Sometimes it is more economical to achieve adequate Effectiveness by employing two small heat exchangers rather than one bigger one. This is the case in the Ames example system. Shown below is a diagram of two exchangers piped in a series-counterflow configuration.



SERIES-COUNTERFLOW CONFIGURATION

STEP 3A. HEAT EXCHANGER SIZING WORKSHEET

CAUTION: The following table is based on the assumptions listed below and is not intended to cover all field applications. For systems that vary from the stated assumptions, contact the ITT Bell & Gossett representative in your area for heat exchanger verification.

HEAT EXCHANGER SELECTION TABLE

Number of Collectors	Heat Exchanger*		Flow Rate (gpm)		Velocity (fps)		Friction Loss (ft. of head)		Shell Diameter (in.)	Shell Length (in.)
	Quantity	Model No.	Shell	Tube	Shell	Tube	Shell	Tube		
4	2	STH-310-4	1.84	1.64	.60	1.22	.9	1.52	3	17
5	2	STH-315-4	2.3	2.04	.74	1.51	1.14	2.36	3	23
9	"	"	4.14	3.68	1.33	2.73	4.3	6.52	"	"
10	2	STH-320-4	4.6	4.08	1.48	3.02	6.8	8.16	3	29
11	"	"	5.06	4.48	1.63	3.32	8.16	10.16	"	"
12	2	STH-415-4	5.52	4.9	1.05	2.11	2.94	2.68	4	23
14	"	"	6.4	5.73	1.22	2.47	3.86	3.16	"	"
15	2	STH-420-4	6.9	6.12	1.32	2.64	5.68	4.26	4	29
18	"	"	8.3	7.3	1.58	3.14	7.94	5.46	"	"
20	"	"	9.2	8.16	1.75	3.5	9.98	7.3	"	"
21	2	STH-520-4	9.66	8.56	1.26	1.68	2.94	2.4	5	30
22	2	STH-530-4	10.12	8.99	1.32	1.77	4.76	2.94	5	42
25	"	"	11.5	10.2	1.5	2.01	5.9	3.84	"	"
30	"	"	13.8	12.25	1.8	2.41	7.48	5.4	"	"
35	"	"	16.1	14.3	2.09	2.81	9.3	6.54	"	"
37	"	"	17.02	15.11	2.22	2.97	12.92	7.1	"	"
38	2	STH-620-4	17.48	15.5	1.56	1.85	4.76	1.9	6	30
39	2	STH-630-4	17.94	15.93	1.6	1.9	6.58	2.7	6	42
40	"	"	18.4	16.32	1.64	1.95	7.72	2.76	"	"
72	"	"	33.12	29.4	2.96	3.51	22.68	5.94	"	"

**Table is based on the following assumptions: 1) The heat exchangers in this table are ITT Bell & Gossett models with a 10° approach; 2) Log mean temperature difference (LMTD) between shell and tube = 10°; 3) Heat exchangers are manifolded in series-counterflow configuration; 4) Collector flow rate is .4 gpm; 5) Temperature drop is the same for collector and Load side loops; 6) Load side flow rate to collector flow rate ratio is .88696; and 7) Solar Incident Radiation is 220 Btuh/sq. ft.*

In the model number STH-315-4, the 3 signifies a 3 inch diameter shell; the 15 signifies a 15 inch tube length; and the [illegible] a 4 pass heat exchanger. (A 4 pass exchanger means each tube winds the length of the shell four times.)

Heat Exchanger Selected: STH-420-4 (2, PIPED IN SERIES - COUNTERFLOW)

SHELL DIAMETER	VOLUMES IN GALLONS PER LINEAR INCH	
	IN SHELL	IN TUBES
4	.036	.019
6	.083	.042
8	.15	.075
10	.2	.1
12	.333	.183
14	.417	.217
16	.542	.291
18	.666	.375
20	.833	.459
24	1.25	.625

AVERAGE WATER VOLUME FOR ITT BELL & GOSSETT SHELL AND TUBE HEAT EXCHANGER

Lab 12: Hydronic Transport System

After the array size has been chosen and placed on the drawing, the storage unit and heat exchanger selected and located, it is time to select pipe sizes and pump required.

Using the Hydronic and Pump Worksheets (attached) as an example, construct worksheets for the following:

1. Select the pipe sizes required to provide fluid flow through the collector array at the rate of .04 - .06 gpm/ft^2 of collector.
2. Fill out the blank spaces on the hydronics worksheet as required.
3. Fill in the blanks on the Pump Worksheet.
4. Make a materials list for the job.

STEP 4. HYDRONIC COMPONENTS SIZING

INTRODUCTION

Step 4 sizes the components associated with movement of a liquid. This step involves a knowledge of basic hydronics. A brief discussion of hydronic terms follows this introduction. Students with limited hydronics backgrounds may find it necessary to consult additional reference sources before continuing the step.

Prior to beginning the hydronic selection process, detailed drawings of the entire system must be made. The designer may want to make a schematic drawing first. This schematic should show all of the pieces and parts of the system and their approximate layout. Such a drawing is helpful prior to making up a bill of materials. A list of schematic symbols and a schematic of the Ames example system are on pages 30 and 31 of this section.

A more refined pictorial drawing should also be made. The exact system layout should be represented, including dimensions between components (this must be known to accurately select certain hydronic components). This type drawing of the Ames example system is on page 32 of this section. A cutaway of the house graphically shows some of the considerations that have to be made when planning the system layout. Note that the collector array is piped in a two row, parallel "Z" flow configuration (see Collector Engineering Handbook sheet in DATA section).

Hydronic components are sized according to the fluid flow demands of each loop. In the typical solar system there are two basic flow demands, one for the collector loop and one for the load side loops. Load side loops consist of the heat exchanger to solar coil loop, heat exchanger to storage loop and storage to solar coil loop.

There are four basic steps to sizing solar hydronic components. Step 4A determines fluid flow demands; Step 4B sizes pipe and determines friction losses; Step 4C balances fluid flow and Step 4D sizes the pump. In addition the collector loop has Step 4E, which sizes the compression tank. It is important to note that the hydronics industry (unlike the refrigeration industry) measures pipe size diameter in nominal inches, which is the outside diameter dimension. Also, copper tubing will carry the fluid in most typical solar systems.

A BRIEF LOOK AT HYDRONIC TERMS AND PRINCIPLES

PRESSURE DROP OR FRICTION LOSS

Pressure drop (sometimes called friction loss) is the term meaning power is consumed in moving fluids through such things as pipes, fittings and heating units. Expressed in another way, pressure drop is the amount of pressure lost between any two points in a system. For example, if the city water pressure at the inlet of a copper coil is 40 pounds per square inch (psi), and at the outlet 35 psi, there is a 5 psi pressure drop through the heater.

Manufacturers who publish pressure drop information on their equipment may express the data either in pounds per square inch, in feet of water, (sometimes called feet of head) or milinches.

These figures are easily interchangeable as follows:

1 psi = 2.3 ft. of water
1 ft. of water = .43 psi
1 ft. of water = 12,000 milinches
Therefore, 1 in. of water = 1000 milinches.

Pressure drop is caused by the friction created between the inner walls of the conveyer and the moving liquid. In a horizontal pipe in which there is no flow, the pressure is equal at all points. The moment flow starts friction is set up, which increases in direct proportion to the velocity of the flow.

To calculate the change in pressure drop when you have an increase or decrease in flow (expressed in gallons per minute or gpm), this simple rule may be followed: "Divide final gpm by initial gpm and square result. Multiply this result by initial pressure drop. This result is the new pressure drop."

The following example shows the effect of increasing the gpm from 3 to 6 in a system with an initial pressure drop of 5 lbs.

$$\left(\frac{\text{Final gpm}}{\text{Initial gpm}}\right)^2 \times \text{Original Pressure Drop} = \text{New Pressure Drop}$$

$$\frac{6}{3} = 2 \quad 2^2 = 4 \quad 4 \times 5 = 20 \text{ psi.}$$

Velocity in feet per second (fps) may be substituted for gpm in this formula.

Therefore, in designing both service water heating systems and hot water space heating systems, pressure drop must be taken into consideration. In each case, enough power must be available to overcome the effects of pressure drop before the desired results can be obtained. This means that the power consumption, or pressure drop, of each component part of a system must be known and a source of sufficient power provided. In a forced hot water heating system this power is provided by the pump — in a domestic water heating system, city water pressure is the source of power.

HEAD PRESSURE

Head pressure is used in designating the capacity of a circulating pump, and is merely another way of expressing pressure drop. The maximum head of a pump is actually the maximum pressure drop against which the pump can induce a flow of liquid. Head pressure is usually expressed in feet of water or feet of head.

STATIC PRESSURE

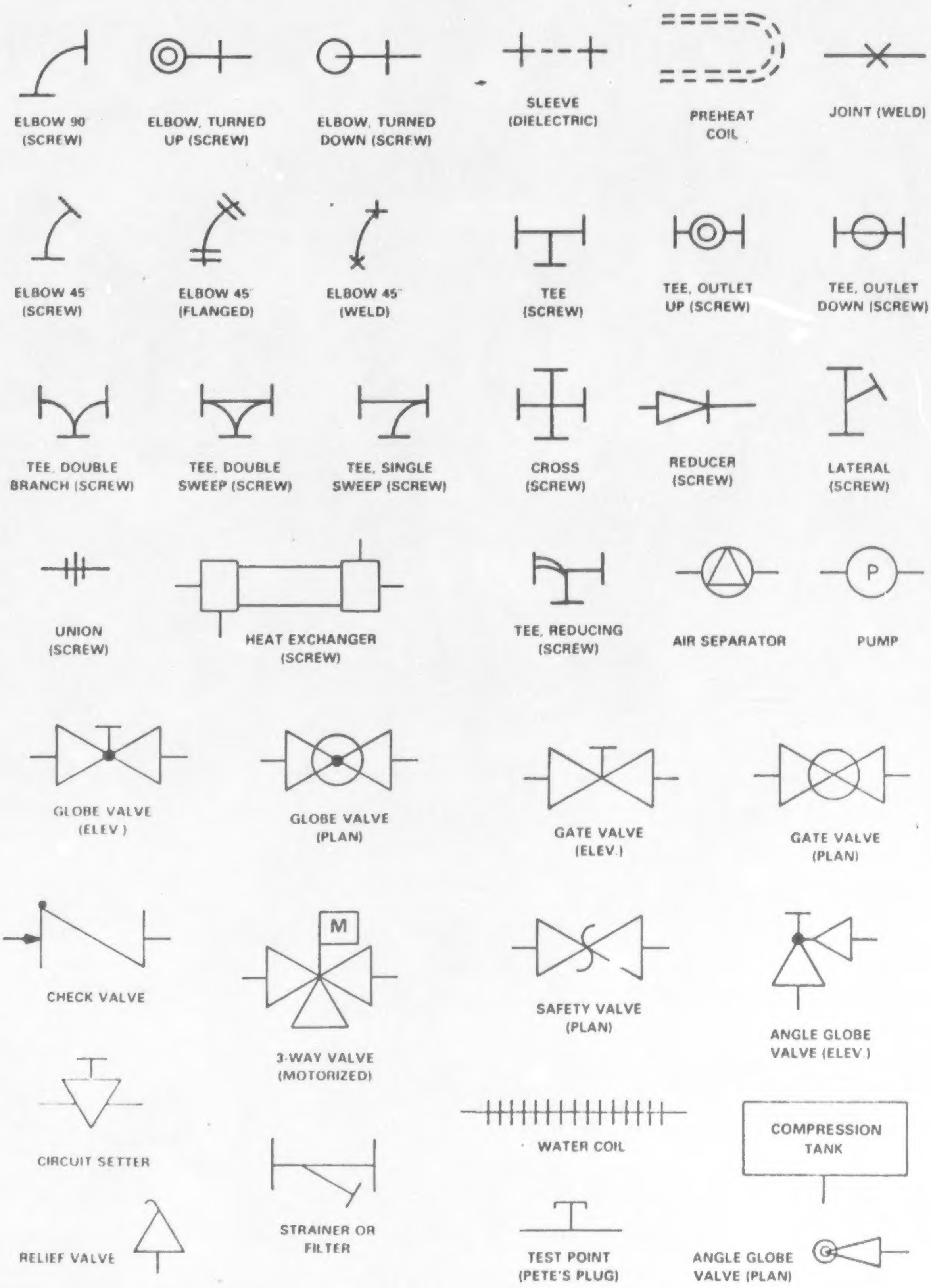
Head pressure should not be confused with static pressure, as they have no relationship. Static pressure is created by the weight of fluid in the system.

Static pressure has no effect on pump capacity in pressurized or closed liquid systems (most solar systems are pressurized). If you will consider a hot water heating system as being an upright loop of water confined in a pipe, the static pressure in one of the vertical pipes of the loop is identical with the pressure at the same level in the opposite vertical pipe.

The static pressure at the point where the pump is installed in a closed system is exactly equalized by the pressure at the same level in the opposite side of the loop. The capacity of the pump, then, is limited only by the friction or head pressure in the system.

In liquid non-pressurized or "open" systems, static pressure must be considered in addition to head pressure in order to size the pump. The static pressure is equal to .43 psi per foot of height above the pump. For example, assume the highest pipe run is 20 feet above the pump. The static pressure at the pump will be 20 times .43, which equals 8.6 psi. At various elevations above the pump, the static pressure becomes correspondingly less. At 10 feet, it is 4.3 psi. At the top pipe run, located 20 feet above the pump, there is no static pressure.

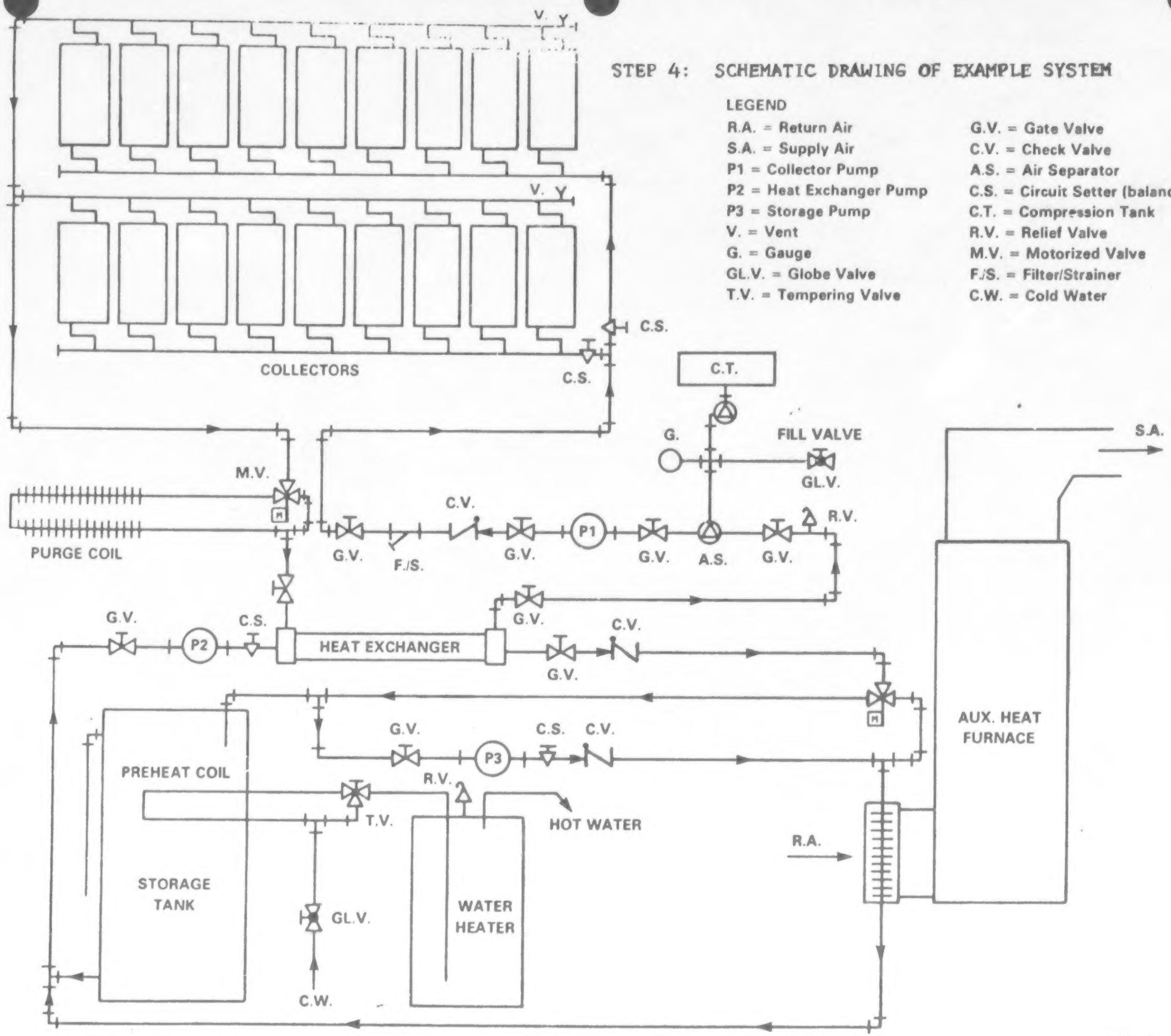
SCHEMATIC SYMBOLS FOR HYDRONIC COMPONENTS


ELBOW 90° (SCREW)
ELBOW, TURNED UP (SCREW)
ELBOW, TURNED DOWN (SCREW)
SLEEVE (DIELECTRIC)
PREHEAT COIL
JOINT (WELD)
ELBOW 45° (SCREW)
ELBOW 45° (FLANGED)
ELBOW 45° (WELD)
TEE (SCREW)
TEE, OUTLET UP (SCREW)
TEE, OUTLET DOWN (SCREW)
TEE, DOUBLE BRANCH (SCREW)
TEE, DOUBLE SWEEP (SCREW)
TEE, SINGLE SWEEP (SCREW)
CROSS (SCREW)
REDUCER (SCREW)
LATERAL (SCREW)
UNION (SCREW)
HEAT EXCHANGER (SCREW)
TEE, REDUCING (SCREW)
AIR SEPARATOR
P
PUMP
GLOBE VALVE (ELEV.)
GLOBE VALVE (PLAN)
GATE VALVE (ELEV.)
GATE VALVE (PLAN)
CHECK VALVE
M
3-WAY VALVE (MOTORIZED)
SAFETY VALVE (PLAN)
ANGLE GLOBE VALVE (ELEV.)
CIRCUIT SETTER
WATER COIL
COMPRESSION TANK
STRAINER OR FILTER
RELIEF VALVE
TEST POINT (PETE'S PLUG)
ANGLE GLOBE VALVE (PLAN)

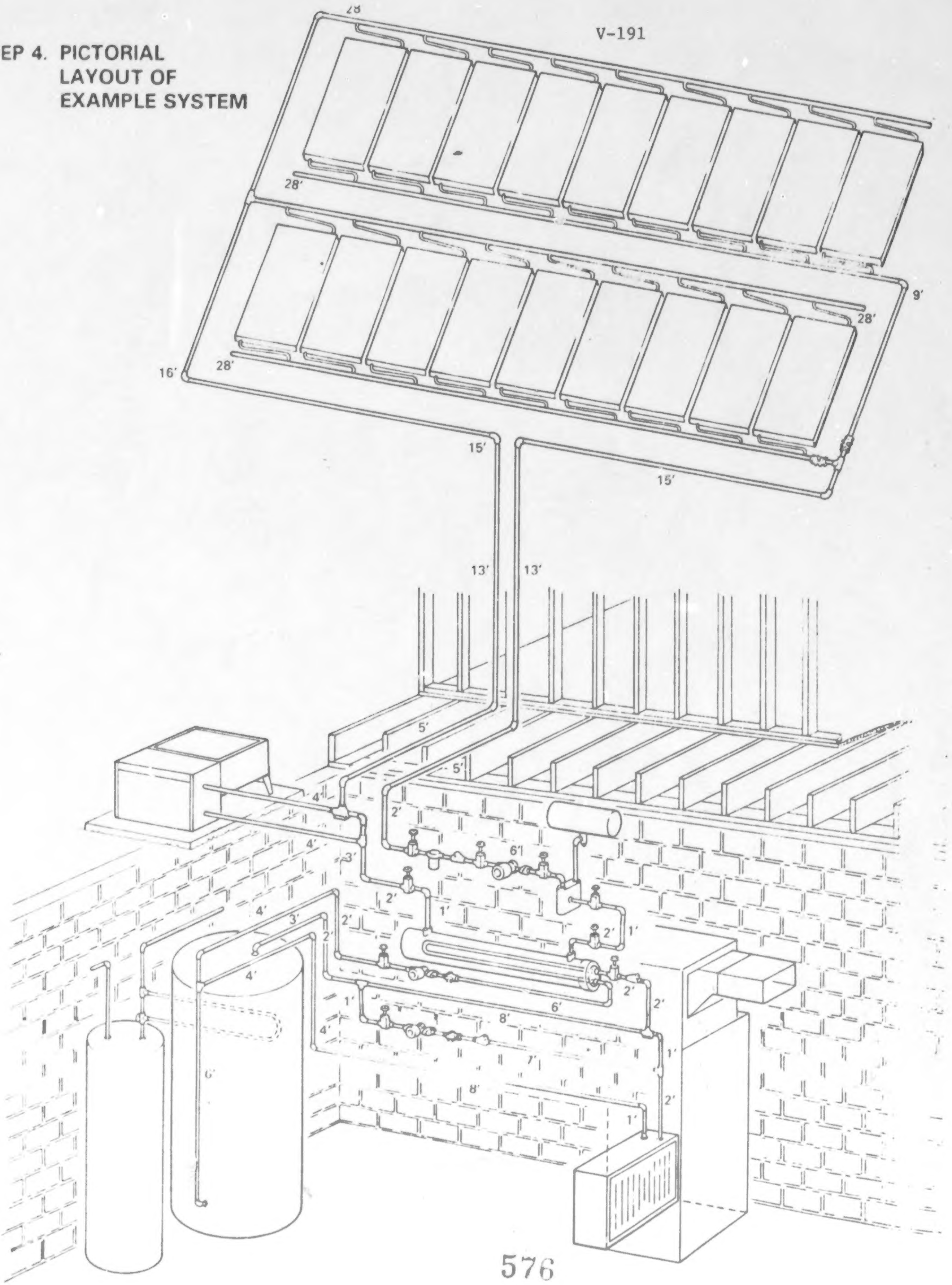
STEP 4: SCHEMATIC DRAWING OF EXAMPLE SYSTEM

LEGEND

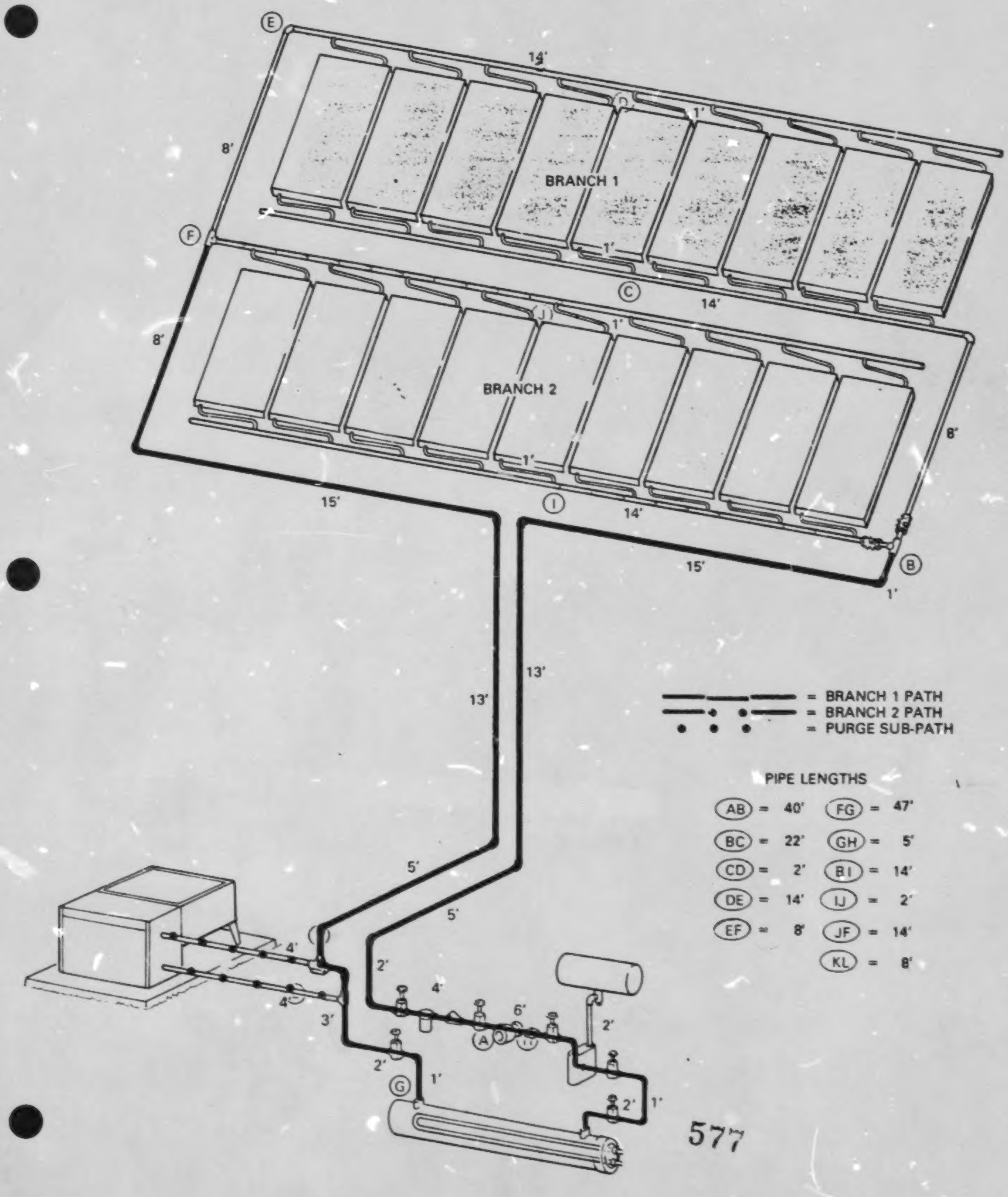
R.A. = Return Air
S.A. = Supply Air
P1 = Collector Pump
P2 = Heat Exchanger Pump
P3 = Storage Pump
V. = Vent
G. = Gauge
GL.V. = Globe Valve
T.V. = Tempering Valve
G.V. = Gate Valve
C.V. = Check Valve
A.S. = Air Separator
C.S. = Circuit Setter (balance valve)
C.T. = Compression Tank
R.V. = Relief Valve
M.V. = Motorized Valve
F./S. = Filter/Strainer
C.W. = Cold Water


V.
V.
COLLECTORS
C.S.
C.S.
C.T.
G.
FILL VALVE
GL.V.
S.A.
M.V.
PURGE COIL
C.V.
G.V.
F./S.
G.V.
P1
G.V.
A.S.
G.V.
R.V.
G.V.
P2
C.S.
HEAT EXCHANGER
G.V.
G.V.
C.V.
AUX. HEAT FURNACE
G.V.
P3
C.S.
C.V.
PREHEAT COIL
T.V.
R.V.
HOT WATER
R.A.
STORAGE TANK
GL.V.
WATER HEATER
C.W.

STEP 4. PICTORIAL LAYOUT OF EXAMPLE SYSTEM


28
28′
9′
28′
16′
28′
15′
15′
13′
13′
5′
5′
4′
2′
4′
3′
6′
2′
1′
2′
1′
4′
3′
2′
2′
4′
2′
2′
1′
6′
8′
4′
7′
1′
6′
8′
2′
1′

STEP 4. COLLECTOR LOOP SIZING


E
14'
D
1'
8'
BRANCH 1
F
1'
C
14'
J
1'
8'
BRANCH 2
8'
1'
15'
I
14'
15'
B
1'
13'
13'
5'
5'
4'
4'
2'
4'
6'
3'
A
H
2'
2'
G
1'
2'
1'

▬▬ = BRANCH 1 PATH
▬ • ▬ = BRANCH 2 PATH
• • • = PURGE SUB-PATH

PIPE LENGTHS

AB = 40'
BC = 22'
CD = 2'
DE = 14'
EF = 8'
FG = 47'
GH = 5'
BI = 14'
IJ = 2'
JF = 14'
KL = 8'

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COLLECTOR LOOP

STEP 4A. FLUID FLOW WORKSHEET

Line 1. Number Of Collectors:

a. Branch 1 (from System Layout Drawing) 9

b. Branch 2 (from System Layout Drawing) 9

c. Branch 3 (from System Layout Drawing) .... —

d. TOTAL Number Of Collectors In System 18

Line 2. Collector Flow Rate:

a. Recommended Flow Rate Through Collector (from Collector Engineering Handbook sheet in DATA section .... 0.4 gpm

b. Correction factor for Ethylene Glycol (from Table 3a of DATA section) 1.15

NOTE: Average temperature of collector loop fluid in most typical systems is approximately 140°F. Enter Table 3a at 140°.

c. Corrected Design Flow Rate:

(Line 2a 0.4) x (Line 2b 1.15) = ... 0.46 gpm

Line 3. Flow Rates:

a. Branch 1 Flow Rate: (Line 1a 9) x (Line 2c 0.46) = 4.14 OR 4.2 gpm

b. Branch 2 Flow Rate: (Line 1b 9) x (Line 2c 0.46) = 4.14 OR 4.2 gpm

c. Branch 3 Flow Rate: (Line 1c —) x (Line 2c —) = — gpm

d. TOTAL Loop Flow Rate .... 8.4 gpm

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR COLLECTOR LOOP – BRANCH I PATH
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) * (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION AB							
1 PIPE	8.4	1 1/4	2.1	40	40.0	40.0	0.80
2 GATE VALVES	"	"	"	—	1.5	3.0	.06
1 CHECK VALVE (SWING)	"	"	"	—	14.0	14.0	.30
5 ELBOWS (ELS) (90° LONG RAD)	"	"	"	—	2.3	11.5	.22
1 TEE (STRAIGHT FLOW)	"	"	"	—	2.3	2.3	.05
1 STRAINER		(FROM TABLE 6B) →					.23
							1.66
SECTION BC							
1 PIPE	4.2	1	1.6	22	22.0	22.0	.35
1 SUDDEN CONTRACTION (.833	"	1 1/4 → 1	"	—	.7	.7	.01
1 EL (90° L.R.)	"	1	"	—	1.7	1.7	.03
1 TEE (BRANCH FLOW)	"	1	"	—	5.0	5.0	.10
NOTE: BALANCE VALVE FRICTION LOSS & SETTING FIGURED IN STEP 4C.							.49
SECTION CD							
1 PIPE (FLEX HOSE)	.46	3/8	1.0	2	2.0	2.0	.04
1 SUDDEN CONTR. (.375"/1"	"	1 → 3/8	"	—	.7	.7	.01
2 ELS OFF COLLECTOR (90° STD	"	3/8	"	—	1.4	2.8	.06
1 TEE (BRANCH FLOW)	"	3/8	"	—	2.7	2.7	.05
1 COLLECTOR		(FROM COLLECTOR EHB DATA) →					.45
							.61
						TOTAL	2,76

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR COLLECTOR LOOP-- BRANCH 1 PATH (CONT.)

USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) * (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION DE							
PIPE 1	4.2	1	1.6	14	14.0	14.0	0.23
SUDDEN ENLARGEMENT (1/2) 1	"	3/8 → 1	"	—	1.4	1.4	.03
EL (80° L.R.) 1	"	1	"	—	1.7	1.7	.02
							.28
SECTION EF							
DOWNRUNNER PIPE 1	4.2	3/4	2.8	8	8.0	8.0	.45
SUDDEN CONTR. (3/4) 1	"	1 → 3/4	"	—	.5	.5	.06
TEE (STRAIGHT FLOW) 1	"	3/4	"	—	1.4	1.4	.10
							.61
SECTION FG							
DOWNRUNNER PIPE 1	8.4	1 1/4	2.1	47	47.0	47.0	.90
SUDDEN ENLARGEMENT (1/2) 1	"	3/4 → 1 1/4	"	—	1.5	1.5	.03
ELS (90° L.R.) 7	"	1 1/4	"	—	2.3	16.1	.30
TEE (STRAIGHT FLOW) 1	"	"	"	—	2.3	2.3	.05
GATE VALVE 1	"	"	"	—	1.5	1.5	.03
3-WAY VALVE (DIVERTER) 1		(CV = 17, FROM TABLE 6C)					.65
							1.96

TOTAL 2.85

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR COLLECTOR LOOP -- BRANCH 1 PATH (CONT.)

USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) * (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION GH							
PIPE 1	8.4	1 1/4	2.1	5	5.0	5.0	.10
ELS (90° L.R.) 4	"	"	"	—	2.3	9.2	.20
GATE VALUES 3	"	"	"	—	1.5	4.5	.09
AIR SEPARATOR (SHARP EDGE) 1	"	"	"	—	ENTRANCE : 5.3 EXIT : 2.6	5.3 + 2.6 = 7.9	.20
HEAT EXCHANGER 1		(FROM STEP 3A WORKSHEET)				→	7.94
							8.53

TOTAL 8.53

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR COLLECTOR LOOP - BRANCH 2 PATH
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION AB			(FIGURED PREVIOUSLY) →				1.66
SECTION B1							
PIPE 1	4.2	1	1.6	14	14.0	14.0	.20
SUDDEN CONTR. (3/4) 1	"	1¼ → 1	"	—	.7	.7	.01
TEE (BRANCH FLOW) 1	"	1	"	—	5.0	5.0	.07
NOTE:	BALANCE VALVE FRICTION LOSS & SETTING FIGURED IN STEP 4C						.28
SECTION 1J							
PIPE (FLEX HOSE) 1	.46	3/8	1.0	2	2.0	2.0	.04
SUDDEN CONTR. (1/4) 1	"	1 → 3/8	"	—	.7	.7	.01
ELS OFF COLLECTOR (90° STD) 2	"	3/8	"	—	1.4	2.8	.06
TEE (BRANCH FLOW) 1	"	"	"	—	2.7	2.7	.05
COLLECTOR 1		(FROM COLLECTOR EMB DATA) →					.45
							.61
SECTION JF							
PIPE 1	4.2	1	1.6	14	14.0	14.0	.20
SUDDEN ENLARGEMENT (1/4) 1	"	3/8 → 1	"	—	1.4	1.4	.02
TEE (BRANCH FLOW) 1	"	1	"	—	5.0	5.0	.07
							.29
SECTION FG			(FIGURED PREVIOUSLY) →				1.96
SECTION GH			(FIGURED PREVIOUSLY) →				8.53

TOTAL 13.33

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR COLLECTOR LOOP -- PURGE SUB-PATH
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in. I.D.) (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION RL							
PIPE 1	8.4	1¼	2.1	8	8.0	8.0	0.16
TEE (BRANCH FLOW) 1	"	"	"	—	7.0	7.0	.14
PURGE COIL 1	(FROM STEP 3B WORKSHEET) →						3.02
							3.32

TOTAL 3.32

COLLECTOR LOOP

STEP 4C. FLOW BALANCE WORKSHEET

Line 1. Friction Loss Of Path(s) (from Step 4B Worksheets)*:

a. Branch 1 Path .... 14.14 ft. of head

b. Branch 2 Path .... 13.33 ft. of head

c. Branch 3 Path .... – ft. of head

Line 2. Friction Loss Correction Factor for Ethylene Glycol (from Table 3b of DATA section) 1.13

NOTE: Average temperature of collector loop fluid in most typical systems is approximately 140°F. Enter Table 3b at 140°.

Line 3. Friction Losses Corrected For Ethylene Glycol:

a. (Path 1 14.14) x (Line 2 1.13) = ... 15.98 ft. of head

b. (Path 2 13.33) x (Line 2 1.13) = ... 15.06 ft. of head

c. (Path 3 –) x (Line 2 –) = ... – ft. of head

d. Path With Greatest Friction Loss (called the Critical Path) = Path 1

Line 4. Determine Presetting Of Critical Path Balance Valve:

a. (Line 3d Critical Path Friction Loss 15.98) x 20% = ... 3.20 ft. of head

b. Use Circuit Setter Calculator Wheel — Preset Side To Determine Setting Needed To Produce Line 4a Friction Loss: .... 1"B.V. 15 ° closed

NOTE: This practice acts as an insurance policy against hydronic sizing miscalculations. Partial closing of this valve in the preset stage allows flow to be adjusted in either direction (increased as well as decreased) in the actual balancing procedure. A circuit setter wheel is in the back pocket of this binder.

It is recommended that a balance valve be installed even if the loop has no branches and should theoretically need no balancing. The balance valve provides a convenient means of adjusting flow for whatever the reason.

Line 5. Design Friction Loss Of Loop:
(Line 3 Critical Path Friction Loss 15.98) + (Line 4a 3.20) = ... 19.18 ft. of head

Line 6. Determine Presetting Of Balance Valve(s) In Non-Critical Path(s):

a. (Line 5 19.18) – (Non-Critical Path Friction Loss From Line 3 15.06) = 4.12 ft. of head

b. Use Circuit Setter Calculator — Preset Side To Determine Setting Needed To Produce Line 6a Friction Loss: .... 1"B.V. 18 ° closed

c. (Line 5 –) – (Non-Critical Path Friction Loss From Line 3 –) = – ft. of head

d. Use Circuit Setter Calculator — Preset Side To Determine Setting Needed To Produce Line 6a Friction Loss: .... – ° closed

NOTE: This action balances or equalizes the loop rates throughout the loop.

*Purge sub-path is not to be considered in the balancing process.

COLLECTOR LOOP

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STEP 4D. PUMP SELECTION WORKSHEET

Collector Loop Not In Purge Cycle

Line 1. a. Design Friction Loss (from Line 5 of Step 4C Worksheet)................... 19.18 ft. of head

b. Design Flow Rate (from Line 3d of Step 4A Worksheet)........................ 8.4 gpm

NOTE: The point on a graph formed by the intersection of the design friction loss and design flow rate is called the system design point. This is the focal point for properly sizing a pump.

Line 2. Select Pump Performance Curve graph (see Tables 7a or 7b in DATA section) whose range is such that the system design point falls near mid-range on the graph.

Line 3. Calculate at least four points of System Performance Curve from the following formula:

$$\left(\frac{Q2}{Q1}\right)^2 = \frac{h2}{h1}$$

Where:

Q2 = final flow (arbitrary number)

Q1 = known flow (from Line 1b)

h2 = final friction loss (this is to be determined)

h1 = known friction loss (from Line 1a)

$$\left(\frac{3}{8.4}\right)^2 = \frac{h2}{19.18} \qquad \left(\frac{5}{8.4}\right)^2 = \frac{h2}{19.18} \qquad \left(\frac{10}{8.4}\right)^2 = \frac{h2}{19.18} \qquad \left(\frac{12}{8.4}\right)^2 = \frac{h2}{19.18}$$

h2 = 2.45 h2 = 6.80 h2 = 27.18 h2 = 39.14

NOTE: The system curve shows how a change in flow affects friction loss, and vice versa. System curve analysis identifies possible system operating characteristics and helps prevent pump sizing mistakes.

Line 4. Plot the system design point and the four (Q2, H2 System Curve) points calculated in Line 3 on Pump Performance Curve graph. (See next page.)

Collector Loop In Purge Cycle

Line 5. Friction Loss Of Purge Sub-Path Corrected For Ethylene Glycol:
(Purge Friction Loss from Step 4B Worksheet 3.32) x
(Correction Factor from Table 3b of DATA section 1.13) = ... 3.75 ft. of head

Line 6. a. Total Friction Loss Of Collector Loop In Purge Cycle:
(Line 1a 19.18) + (Line 5 3.75) = ... 22.93 ft. of head

b. Design Flow Rate (from Line 3d of Step 4A Worksheet)........................ 8.4 gpm

NOTE: The intersection of the above numbers on a graph is the system design point.

Line 7. Calculate at least four points of System Performance Curve In Purge Cycle (use formula from Line 3 with one exception; h1 figure is from Line 6a instead of Line 1a):

$$\left(\frac{3}{8.4}\right)^2 = \frac{h2}{22.93} \qquad \left(\frac{5}{8.4}\right)^2 = \frac{h2}{22.93} \qquad \left(\frac{10}{8.4}\right)^2 = \frac{h2}{22.93} \qquad \left(\frac{12}{8.4}\right)^2 = \frac{h2}{22.93}$$

h2 = 2.92 h2 = 8.12 h2 = 32.50 h2 = 46.80

Line 8. Plot the system design point and the four (Q2, h2) points calculated in Line 7 on Pump Performance Curve graph. (See next page.)

Pump Selection

Line 9. Select pump whose performance curve is nearest the system design point. If the design point is equidistant between two pump curves, normally size to the higher pump curve. The system design point should also intersect the pump curve in the middle one-third range of pump curve, or slightly left of middle.

Pump Selected: rpm 1750 hp 1/4 impeller $4\frac{11}{16}$ model no. 1AA, SERIES 60

NOTE: Since system will be operating "not in purge" more than "in purge", the pump normally should be sized to the "not in purge" design point. Check "in purge" system curve to see that the reduced gpm output of the pump in purge will not significantly affect system operation.

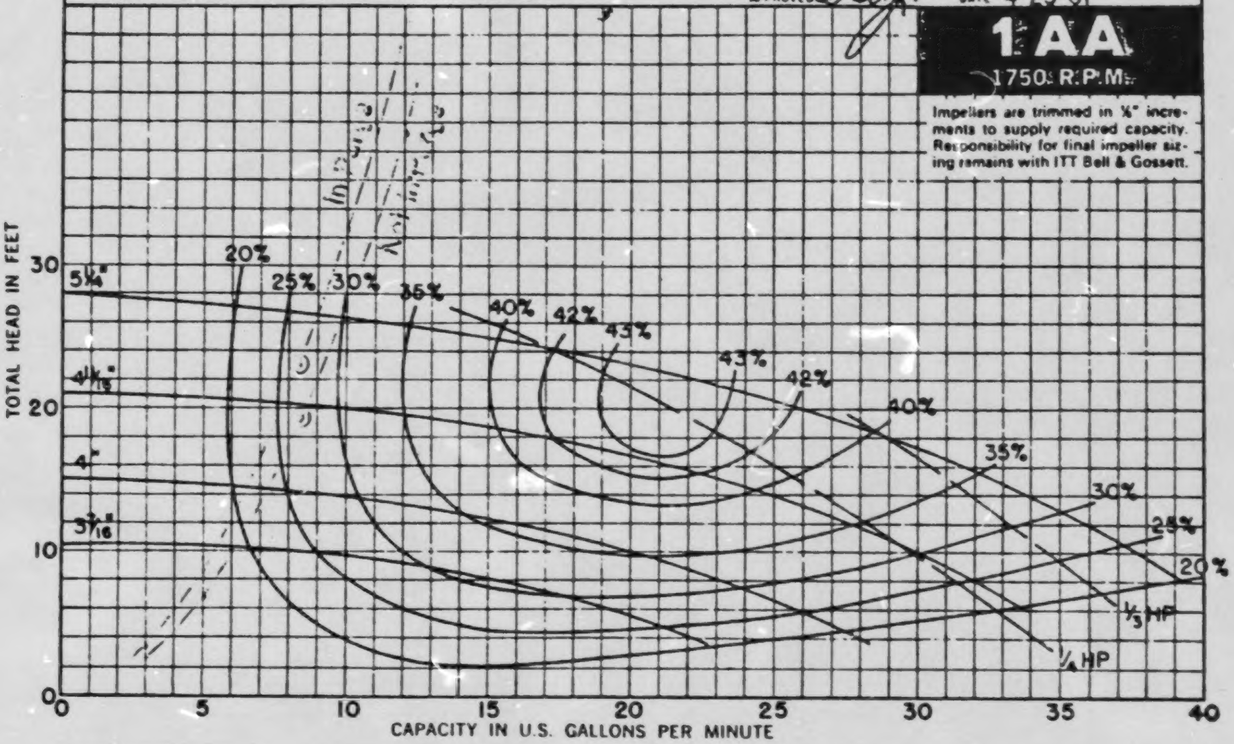
TABLE 7a. PUMP PERFORMANCE CURVES — ITT BELL & GOSSETT

PERFORMANCE CHARACTERISTIC CURVE

FOR 1"AA CENTRIFUGAL PUMP FIG NO SERIES 60 SPEED 1750 R P M

CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

APPROVED RWJ. DATE 4-25-61



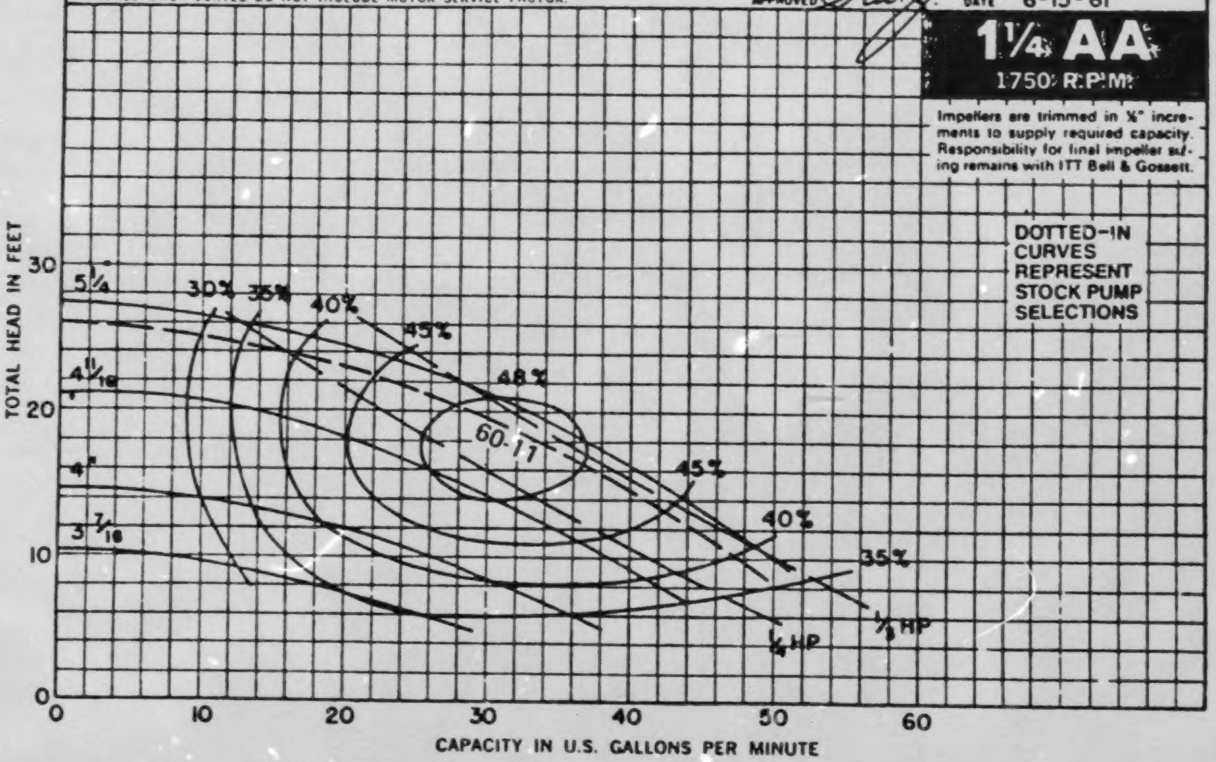
Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

PERFORMANCE CHARACTERISTIC CURVE

FOR 1¼"AA CENTRIFUGAL PUMP FIG NO SERIES 60 SPEED 1750 R P M

CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

APPROVED RWJ. DATE 6-15-61



Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

DOTTED-IN CURVES REPRESENT STOCK PUMP SELECTIONS

COLLECTOR LOOP

V-213

STEP 4E. COMPRESSION TANK SELECTION WORKSHEET

Line 1. Determine Volume Of Fluid In Piping:

SIZE (from System Layout Drawing)	:	LENGTH (from System Layout Drawing)	x	GAL/FT (from Table 8a of DATA section)	=	VOLUME	
1¼"	:	(40+47+5+8)= 100	x	0.078	=	7.80	gal.
1"	:	(28+28+36+28)=120	x	0.045	=	5.40	gal.
3/4"	:	8'	x	0.028	=	0.22	gal.
3/8"	:	(18x2) = 36'	x	0.007	=	0.25	gal.
	:		x		=		gal.
				TOTAL		13.67	gal.

Line 2. Determine Volume Of Fluid In The Following Components:

a. Collectors:
(Collector Fluid Capacity, from Engineering Handbook data 0.3) x
(Number Of Collectors, from Line 1d of Step 4A Worksheet 18) = 5.40 gal.

b. Heat Exchanger — shell (from Step 3A Worksheet):
(No. of Exchangers 2) x (Shell Length 29) x (Gal/Linear Inch .036) = 2.09 gal.

c. Purge Coil (from Step 3B Worksheet specifications)........ 1.03 gal.

d. Pump (from pump specifications)........ 0.50 gal.

e. Strainer (from strainer specifications)........ 0.50 gal.

f. Air Separator (from air separator specifications)........ 1.00 gal.

TOTAL 10.52 gal.

Line 3. Total Volume Of Fluid: (Line 1 TOTAL 13.67) + (Line 2 TOTAL 10.52) = 24.19 gal.

Line 4. Correct Total Volume for Ethylene Glycol:
(Line 3 24.19) x (Correction Factor from Table 3c of DATA section 1.5) = 36.28 gal.
NOTE: Maximum design temperature of most typical systems is 200°F. Enter Table 3c at 200°.

Line 5. Determine Tank Capacity Requirements Based on Line 4 figure
(from Table 8b of DATA section)........ 5.3 gal.
NOTE: Enter Table 8b at 200°F.

Line 6. Select Compression Tank (from Table 8c of DATA section):
Model no. 15, ASME CONSTRUCTION Gal. capacity 15

STEP 4. SIZING LOAD SIDE LOOPS

Load Side Loop Identification:

Heat Exchanger to Solar Heat Coil Loop = Segments Ⓐ, Ⓑ, Ⓒ, Ⓓ, Ⓔ, Ⓕ

Heat Exchanger to Storage Loop= Segments Ⓐ, Ⓑ, Ⓖ, Ⓗ, Ⓘ, Ⓕ

Storage to Solar Heat Coil Loop =Segments Ⓙ, Ⓒ, Ⓓ, Ⓔ, Ⓘ, Ⓗ, Ⓖ, Ⓚ

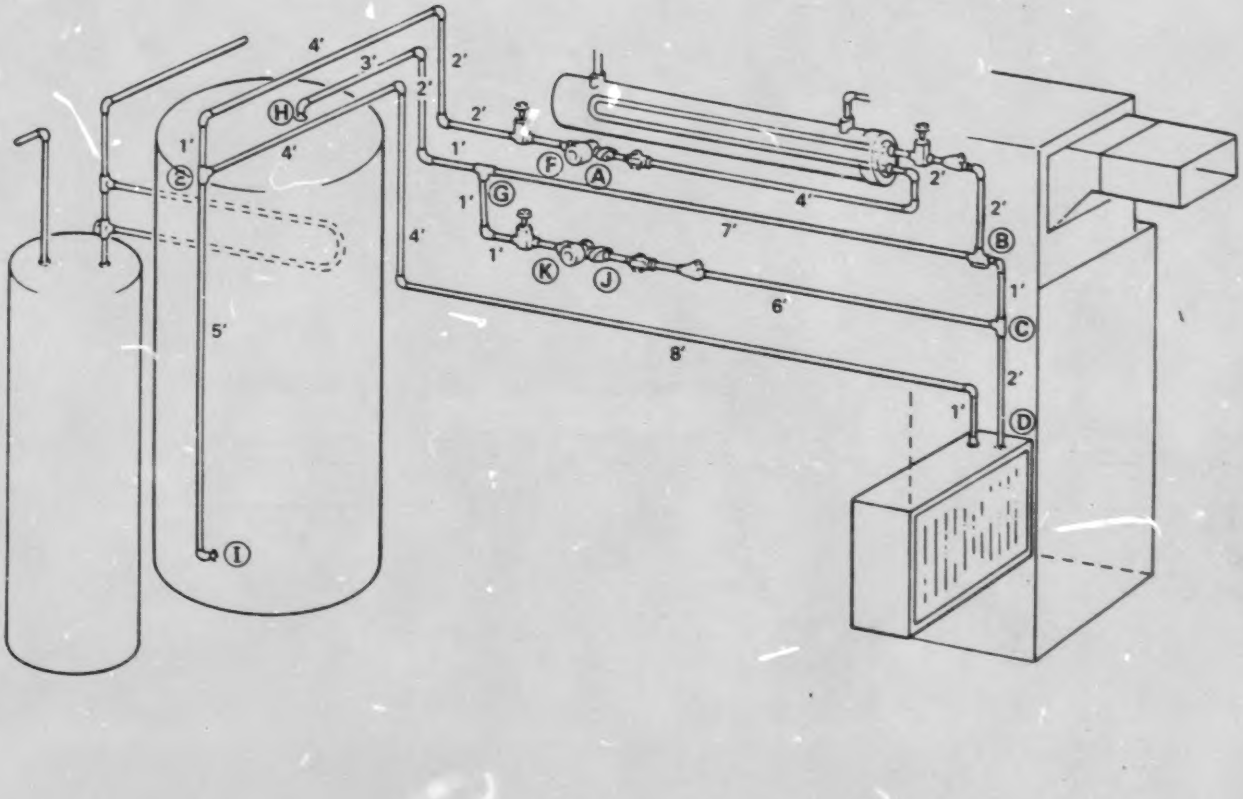
NOTE: Where there is bidirectional fluid flow in piping segments that contain vertical runs, size pipe according to a downrunner consideration.

PIPE LENGTHS

(AB) = 8'
(BC) = 1'
(CD) = 2'

(DE) = 17'
(EF) = 9'
(BG) = 7'

(GH) = 6' (bidirectional & vertical, size to downrunner)
(IE) = 5' (bidirectional & vertical, size to downrunner)
(JC) = 6'
(GK) = 2'



LOAD SIDE LOOPS

STEP 4A. FLUID FLOW WORKSHEET

Line 1a. Total Effective Absorber Area Of Collector Array .... 277 sq. ft.

b. Solar Radiation Incidence (from Table 9 of DATA section) .... 220 Btuh/sq. ft.

c. Solar Load To Be Transferred Through Heat Exchanger:
(Line 1a 277) x (Line 1b 220) = ... 60940 Btuh

Line 2. Temperature Drop Across Heat Exchanger:

(Line 1c 60940)
(Line 3d of Collector Loop Fluid Flow Worksheet 8.4) x 444 (Heat carrying factor for glycol) = ... 16.34 °F

NOTE: Temperature drop across both shell and tube sides of heat exchanger is the same.

Line 3. Flow Rate For Load Side Loops:

(Line 1c 60940)
(Line 2 16.34) x 500 (heat carrying factor for water) = ... 7.46 OR 7.5 gpm

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR LOAD SIDE -- HEAT EXCH. TO SOLAR HEAT COIL LOOP
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)		Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION AB								
DOWNRUNNER PIPE	1	7.5	1	2.9	8	8.0	8.0	0.32
ELS (90° L.R.)	3	"	"	"	—	1.7	5.1	.20
GATE VALVE	1	"	"	"	—	1.0	1.0	.04
CHECK VALVE (SWING)	1	"	"	"	—	10.0	10.0	.40
HEAT EXCHANGER	1		(FROM STEP 3A WORKSHEET)				→	5.46
NOTE: BALANCE VALVE FRICTION LOSS AND PRESETTING FIGURED IN STEP 4C.								6.42
SECTION BC								
DOWNRUNNER PIPE	1	7.5	1	2.9	1	1.0	1.0	.04
EL (90° L.R.)	1	"	"	"	—	1.7	1.7	.07
3-WAY VALVE (DIVERT)	1		(CV = 13, FROM TABLE 6C)				→	.90
								1.11
SECTION CD								
DOWNRUNNER PIPE	1	7.5	1	2.9	2	2.0	2.0	.08
TEE (STR FLOW)	1	"	"	"	—	1.7	1.7	.07
								.15
SECTION DE								
PIPE	1	7.5	1¼	1.8	17	17.0	17.0	.27
ELS (90° L.R.)	3	"		"	—	2.3	6.9	.10
SOLAR COIL	1		(FROM STEP 3D WORKSHEET)				→	6.00
								6.37
							TOTAL	14.05

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR LOAD SIDE -- HEAT EXCH. TO SOLAR COIL LOOP (CONTINUED)
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION EF							
DOWNRUNNER PIPE 1	7.5	1	2.9	9	9.0	9.0	0.36
SUDDEN CONTRACTION (3/4) 1	"	1¼→1	"	—	.7	.7	.03
TEE (BRANCH FLOW 1	"	1	"	—	5.0	5.0	.20
ELS (90° L.R.) 3	"	"	"	—	1.7	5.1	.20
GATE VALVE 1	"	"	"	—	1.0	1.0	.04
							.83

TOTAL .83

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR LOAD SIDE--HEAT EXCH. TO STORAGE LOOP
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION AB		(FIGURED PREVIOUSLY)				→	6.42
SECTION BG							
PIPE 1	7.5	1¼	1.8	7	7.0	7.0	.11
SUDDEN ENLARGEMENT (3/4) 1	"	1→1¼	"	—	.7	.7	.03
3-WAY VALVE (DIVERT) 1		(CV=13, FROM TABLE 6C)				→	.90
							1.04
SECTION GH							
BIDIRECTIONAL DOWNRUNNER PIPE 1	7.5	1	2.9	6	6.0	6.0	.24
SUDDEN CONTR. (3/4) 1	"	1¼→1	"	—	.7	.7	.03
TEE (STRAIGHT FLOW) 1	"	1	"	—	1.7	1.7	.07
ELS (90° L.R.) 3	"	"	"	—	1.7	5.1	.20
							.54
SECTION HI							
STORAGE TANK ENTRANCE LOSS (SHARP EDGE) 1	7.5	1	2.9	—	3.7	3.7	.15
STORAGE TANK EXIT LOSS (SHARP) 1	"	"	"	—	1.8	1.8	.07
							.22
SECTION IE							
BIDIRECTIONAL DOWNRUNNER PIPE 1	7.5	1	2.9	5	5.0	5.0	.20
EL (90° L.R.) 1	"	"	"	—	1.7	1.7	.07
							.27
SECTION EF		(FIGURED PREVIOUSLY)				→	.83

TOTAL 9.32

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR LOAD SIDE -- STORAGE TO SOLAR COIL LOOP
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION JC							
PIPE 1	7.5	1¼	1.8	6	6.0	6.0	0.10
CHECK VALVE (SWING 1	"	"	"	—	14.0	14.0	.22
NOTE: BALANCE VALVE FRICTION LOSS & PRESETTING FIGURED IN STEP 4C.							.32
SECTION CD							
DOWNRUNNER PIPE 1	7.5	1	2.9	2	2.0	2.0	.08
SUDDEN CONTR. (3/4) 1	"	1¼ → 1	"	—	.7	.7	.03
TEE (BRANCH FLOW) 1	"	1	"	—	5.0	5.0	.20
							.31
SECTION DE		(FIGURED PREVIOUSLY) →					6.37
SECTION EI		(FIGURED PREVIOUSLY) →					.27
SECTION IH		(FIGURED PREVIOUSLY) →					.22
SECTION HG		(FIGURED PREVIOUSLY) →					.54
			(CONTINUED)				
						TOTAL	8.03

STEP 4B. MASTER HYDRONICS WORKSHEET

FOR LOAD SIDE -- STORAGE TO SOLAR COIL LOOP (CONTINUED)
USED TO SIZE PIPE & DETERMINE FRICTION LOSS

Col. A SECTION & COMPONENT (from System Layout Drawing)	Col. B FLUID FLOW (gpm) (from Line 3 of Step 4A Worksheet)	Col. C PIPE SIZE (in., I.D.) (from Table 4 of DATA section) NOTE—Enter size on System Layout Drawing.	Col. D VELOCITY (fps) (from Table 4 of DATA section)	Col. E PIPE LENGTH (ft.) (from System Layout Drawing)	Col. F EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.) (from Tables 5a, 5b or 5c of DATA Section)	Col. G TOTAL EQUIVALENT LENGTH OF STANDARD FITTINGS (ft.): (Col. A) x (Col. F)	Col. H. FRICTION LOSS (ft of head) (from Tables 6a, 6b or 6c of DATA section or Step 3A, 3B, 3C or 3D Worksheets
SECTION GK							
DOWNRUNNER PIPE 1	7.5	1	2.9	2	2.0	2.0	.08
TEE (BRANCH FLOW) 1	"	"	"	—	5.0	5.0	.20
EL (90° L.R.) 1	"	"	"	—	1.7	1.7	.07
GATE VALVE 1	"	"	"	—	1.0	1.0	.04
							.39

TOTAL .39

LOAD SIDE LOOPS

STEP 4C. FLOW BALANCE WORKSHEET

Line 1. Friction Losses (from Step 4B Worksheets):

a. Heat Exchanger to Solar Heat Coil Loop .... 14.88 ft. of head

b. Heat Exchanger to Storage Loop .... 9.32 ft. of head

c. Storage To Solar Heat Coil Loop .... 8.42 ft. of head

NOTE: Since one pump operates both heat exchanger to solar coil and heat exchanger to storage loops, each is actually a branch flow path. As in the collector loop sizing procedure, the critical path must be determined to properly select the pump. Unlike the collector loop, the non-critical path flow is not balanced. This is because the increased flow rate will result in a heat transfer advantage that outweighs installing a balance valve.

The storage to solar coil loop has its own pump and only one flow path, which is considered the critical path.

Critical Paths: Heat Exch. to Coil Loop
Storage to Solar Coil Loop

Line 2. Determine Presettings Of Critical Path Balance Valves:

a. (Line 1 Critical Path Friction Loss 14.88) x 30% = ... 4.46 ft. of head

b. Use Circuit Setter Calculator—Preset Side to determine setting needed to produce Line 2a friction loss: .... 1"B.V., 5 ° closed

c. (Line 1 Critical Path Friction Loss 8.42) x 40% = ... 3.37 ft. of head

d. Use Circuit Setter Calculator—Preset Side to determine setting needed to produce Line 2c friction loss: .... 1¼"B.V., 26° ° closed

Line 3. Design Friction Losses:

a. (Line 1 Critical Path Friction Loss 14.88) +(Line 2a 4.46) = 19.34 ft. of head

b. (Line 1 Critical Path Friction Loss 8.42) + (Line 2c 3.37) = 11.79 ft. of head

LOAD SIDE LOOPS

STEP 4D. PUMP SELECTION WORKSHEET

Heat Exchanger to Solar Coil & Heat Exchanger to Storage Loop Pump

Line 1a. Design Friction Loss (from Line 3a of Step 4C Worksheet) .... 19.34 ft. of head

b. Design Flow Rate (from Line 3 of Step 4A Worksheet) .... 7.5 gpm

NOTE: The intersection of the above numbers on a graph is the system design point.

Line 2. Select Pump Performance Curve graph (See Tables 7a or 7b in DATA section) whose range is such that the system design point falls near mid-range on graph.

Line 3. Calculate at least 4 points of System Performance Curve from the following formula:

$$\left(\frac{Q2}{Q1}\right)^2 = \frac{h2}{h1}$$

Where:

Q2 = final flow (arbitrary number)

Q1 = known flow (from Line 1b)

h2 = final friction loss (this is to be determined)

h1 = known friction loss (from Line 1a)

$$\left(\frac{3}{7.5}\right)^2 = \frac{h2}{19.34} \qquad \left(\frac{5}{7.5}\right)^2 = \frac{h2}{19.34} \qquad \left(\frac{10}{7.5}\right)^2 = \frac{h2}{19.34} \qquad \left(\frac{12}{7.5}\right)^2 = \frac{h2}{19.34}$$

h2 = 3.09 h2 = 8.6 h2 = 34.38 h2 = 49.51

Line 4. Plot the system design point and the 4 (Q2, h2) System Curve points calculated in Line 3 on Pump Performance Curve graph. (See example on next page.)

Line 5. Select pump whose performance curve is nearest the system design point. If the design point is equidistant between two pump curves, normally size to the higher pump curve. The system design point should also intersect the pump curve in the middle one-third range of pump curve, or slightly left of middle.

Pump Selected: rpm 1750 hp 1/4 impeller 4 1/16 model no. 1AA, SERIES 60

Storage to Solar Coil Loop Pump

Line 6a. Design Friction Loss (from Line 3b of Step 4C Worksheet) .... 11.79 ft. of head

b. Design Flow Rate (from Line 3 of Step 4A Worksheet) .... 7.5 gpm

NOTE: The intersection of the above numbers on a graph is the system design point.

Line 7. Select Pump Performance Curve graph (see Tables 7a or 7b in DATA section) whose range is such that the system design point falls near mid-range on graph.

Line 8. Calculate at least 4 points of System Performance Curve (use formula from Line 3 with one exception; h1 is from Line 6a instead of Line 1a):

$$\left(\frac{3}{7.5}\right)^2 = \frac{h2}{11.79} \qquad \left(\frac{5}{7.5}\right)^2 = \frac{h2}{11.79} \qquad \left(\frac{8}{7.5}\right)^2 = \frac{h2}{11.79} \qquad \left(\frac{10}{7.5}\right)^2 = \frac{h2}{11.79}$$

h2 = 1.89 h2= 5.24 h2= 13.41 h2= 20.96

Line 9. Plot the system design point and the 4 (Q2, h2) System Curve points calculated in Line 8 on Pump Performance Curve graph. (See example on next page.)

Line 10. Select pump using same rationale as in Line 5 above.

Pump Selected: rpm 3200 hp — impeller — model no. UP 26-64

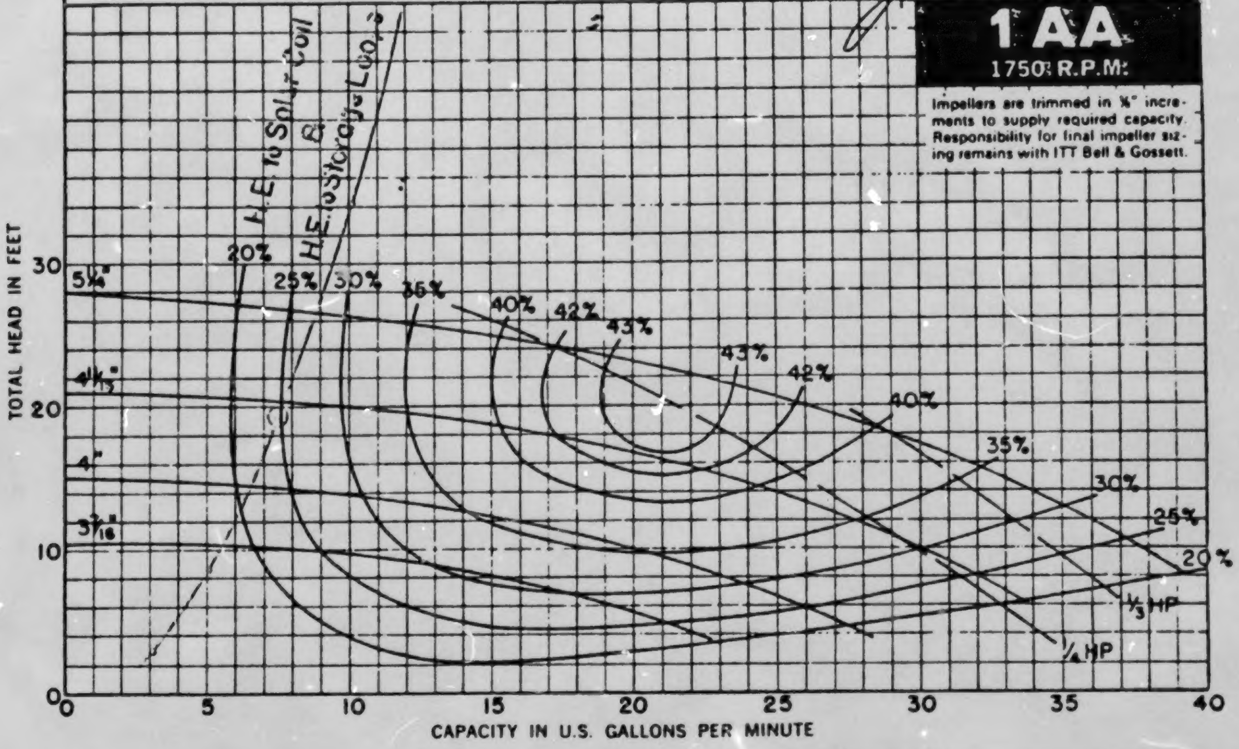
TABLES 7a. PUMP PERFORMANCE CURVES — ITT BELL & GOSSETT

PERFORMANCE CHARACTERISTIC CURVE

FOR 1"AA CENTRIFUGAL PUMP FIG NO SERIES 60 SPEED 1750 R P M

CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

APPROVED RWJ. DATE 4-25-61



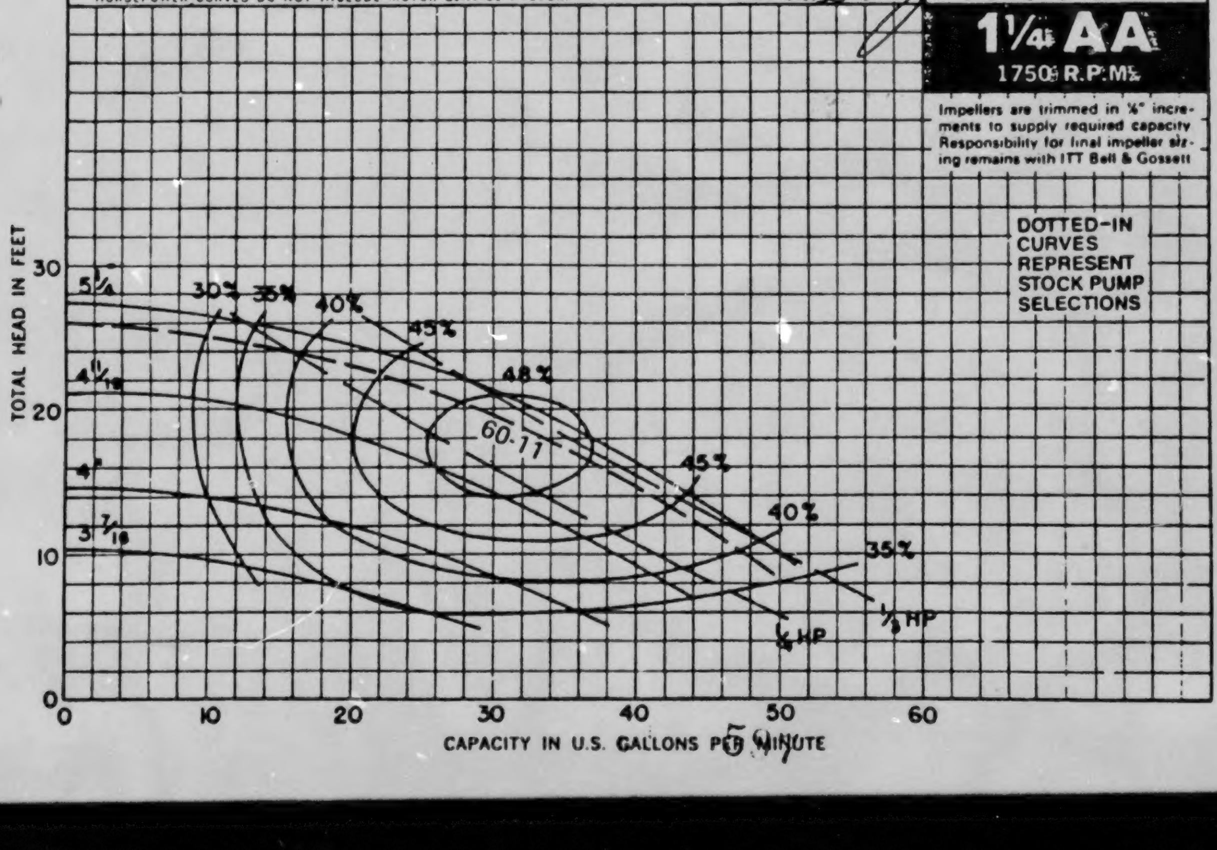
Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

PERFORMANCE CHARACTERISTIC CURVE

FOR 1¼"AA CENTRIFUGAL PUMP FIG NO SERIES 60 SPEED 1750 R P M

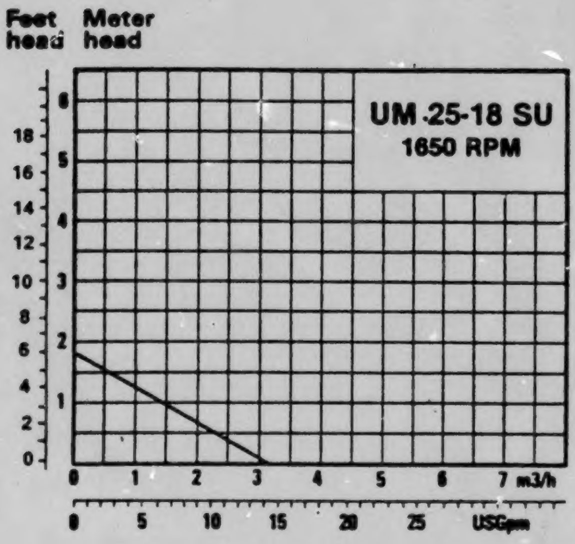
CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

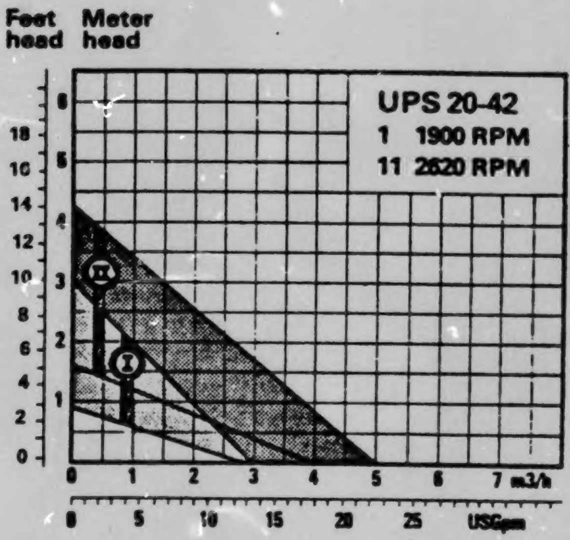
APPROVED RWJ. DATE 6-15-61



Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

DOTTED-IN CURVES REPRESENT STOCK PUMP SELECTIONS


Feet head
Meter head
UM 25-18 SU
1650 RPM
0
2
4
6
8
10
12
14
16
18
1
2
3
4
5
6
0
1
2
3
4
5
6
7 m3/h
0
5
10
15
20
25
USGpm


Feet head
Meter head
UPS 20-42
1 1900 RPM
11 2620 RPM
0
2
4
6
8
10
12
14
16
18
1
2
3
4
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1
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3
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6
7 m3/h
0
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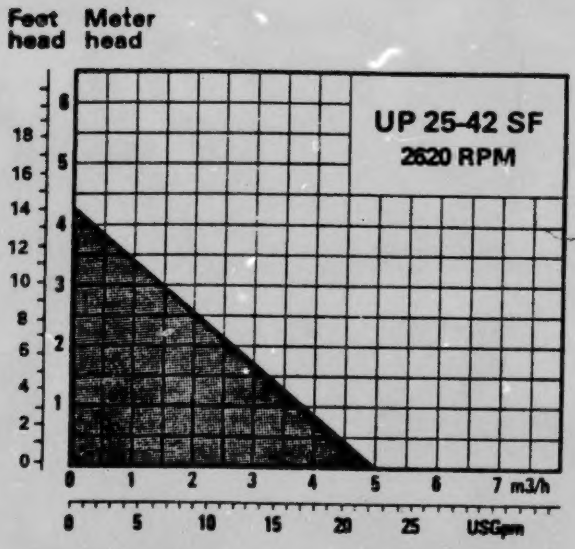
10
15
20
25
USGpm


Feet head
Meter head
UP 25-42 SF
2620 RPM
0
2
4
6
8
10
12
14
16
18
1
2
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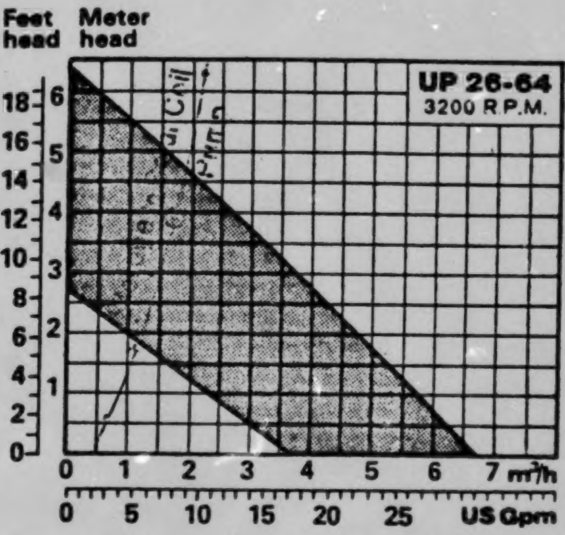
5
10
15
20
25
USGpm


Feet head
Meter head
UP 26-64
3200 R.P.M.
0
2
4
6
8
10
12
14
16
18
1
2
3
4
5
6
0
1
2
3
4
5
6
7 m³/h
0
5
10
15
20
25
US Gpm

TABLES 3a, 3b & 3c. ETHYLENE GLYCOL CORRECTION FACTORS

TABLE 3a. FLOW CORRECTION FACTORS

Fluid Temp. °F.	Flow Increase Need for 50% Glycol as compared with Water
40	1.22
100	1.16
140	1.15
180	1.14
220	1.14

TABLE 3b. FRICTION LOSS CORRECTION FACTORS (For Turbulent Flow Only)

Fluid Temperature °F.	Friction Loss Correction Factors For 50% Glycol
40	1.47
100	1.22
140	1.13
180	1.11
220	1.06

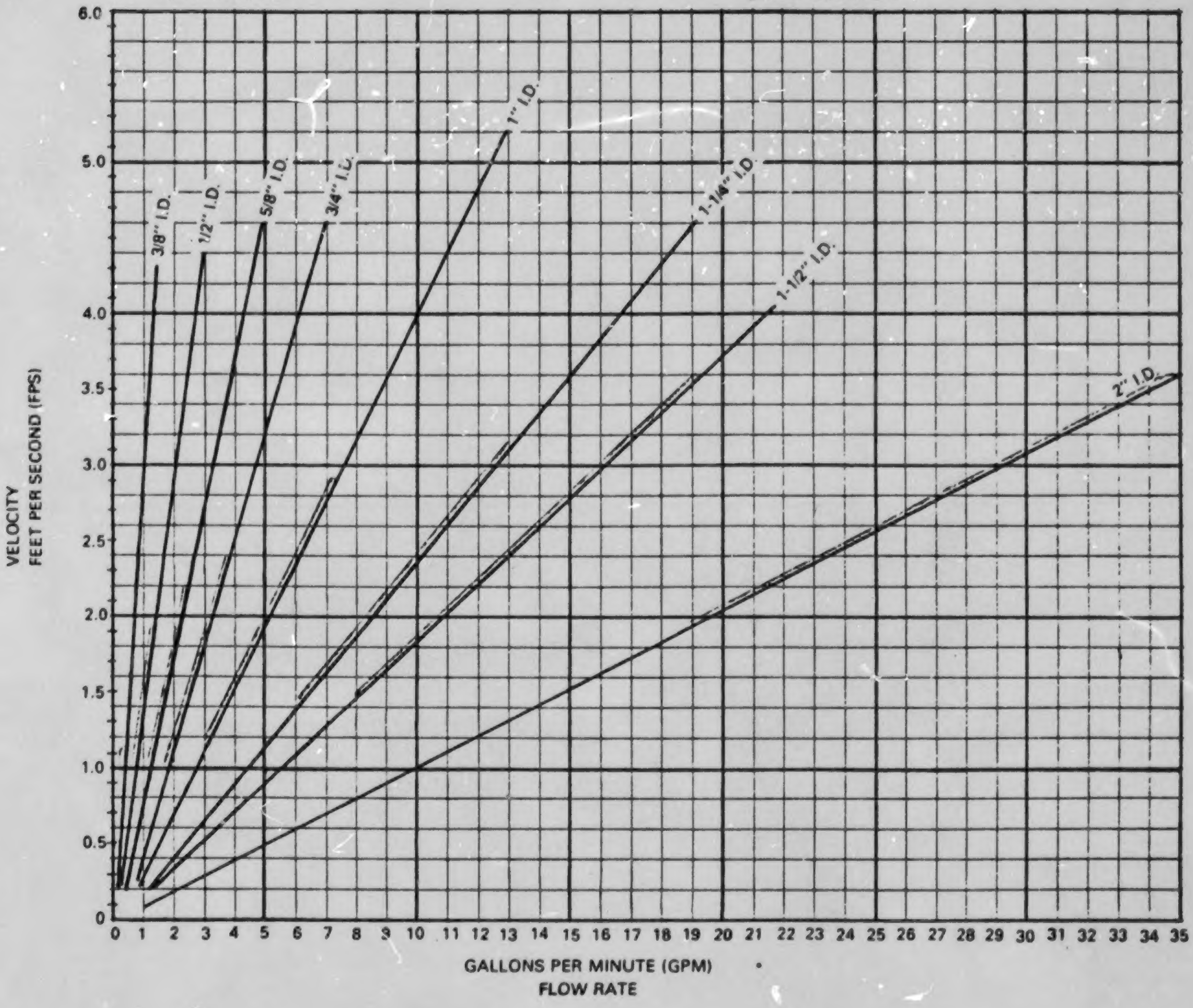
TABLE 3c. VOLUME CORRECTION FACTORS

PERCENT OF ETHYLENE GLYCOL BY VOLUME	APPROX. FREEZE PT. °F	MAXIMUM DESIGN TEMPERATURE					
		150°	160°	180°	200°	220°	240°
10%	+25°	1.15	1.13	1.1	1.09	1.08	1.05
20%	+16°	1.31	1.29	1.24	1.18	1.15	1.12
33%	0°	1.6	1.52	1.44	1.37	1.3	1.23
50%	-34°	1.8	1.73	1.6	1.5	1.42	1.36

TABLE 4. PIPE SIZE CHART

NOTE 1: Color bands denotes acceptable pipe size with respect to friction loss.

NOTE 2: Minimum velocity for downrunner pipe should be greater than 2 fps.



TABLES 5a, 5b & 5c. EQUIVALENT LENGTHS (ft. of pipe) FOR STANDARD HYDRONIC FITTINGS

NOTE: 1 foot of straight pipe = 1 equivalent foot of pipe.

Table 5a. Valve Equivalent Feet of Pipe *

(Screwed, Welded, Flanged, and Flared Connections)

Nominal Pipe or Tube Size (in.)	Globe [a]	60°-Y	45°-Y	Angle [a]	Gate [b]	Swing Check [c]	Lift Check
3/8	17	8	6	6	0.6	5	Globe & Vertical Lift Same as Globe Valve [d]
1/2	18	9	7	7	0.7	6	
3/4	22	11	9	9	0.9	8	
1	29	15	12	12	1.0	10	
1-1/4	38	20	15	15	1.5	14	
1-1/2	43	24	18	18	1.8	16	
2	55	30	24	24	2.3	20	
2-1/2	69	35	29	29	2.8	25	
3	84	43	35	35	3.2	30	
3-1/2	100	50	41	41	4.0	35	
4	120	58	47	47	4.5	40	
5	140	71	58	58	6	50	
6	170	88	70	70	7	60	
8	220	115	85	85	9	80	
10	280	145	105	105	12	100	
12	320	165	130	130	13	120	Angle Lift Same as Angle Valve
14	360	185	155	155	15	135	
16	410	210	180	180	17	150	
18	460	240	200	200	19	165	
20	520	275	235	235	22	200	
24	610	320	265	265	25	240	

* Losses are for all valves in fully open position.

[a] These losses do not apply to valves with needle point type seats.

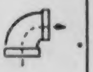
[b] Regular and short pattern plug cock valves, when fully open, have same loss as gate valve. For valve losses of short pattern plug cocks above 6 in., check manufacturer.

[c] Losses also apply to the in-line, ball type check valve.

[d] For Y pattern globe lift check valve with seat approximately equal to the nominal pipe diameter, use values of 60°Y valve for loss.

Table 5b. Fitting Losses in Equivalent Feet of Pipe

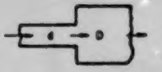
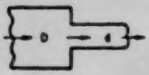
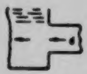
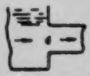
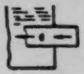
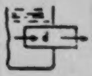
(Screwed, Welded, Flanged, Flared, and Brazed Connections)

Nominal Pipe or Tube Size (in.)	Smooth Bend Elbows						Smooth Bend Tees			
	90° Standard*	90° Long Radius†	90° Street* 	45° Std*	45° Street*	180° Standard*	Flow Through Branch	Straight-Through Flow		
								No Reduction	Reduced 1/4	Reduced 1/2
3/8	1.4	0.9	2.3	0.7	1.1	2.3	2.7	0.9	1.2	1.4
1/2	1.6	1.0	2.5	0.8	1.3	2.5	3.0	1.0	1.4	1.6
3/4	2.0	1.4	3.2	0.9	1.6	3.2	4.0	1.4	1.9	2.0
1	2.6	1.7	4.1	1.3	2.1	4.1	5.0	1.7	2.3	2.6
1-1/4	3.3	2.3	5.6	1.7	3.0	5.6	7.0	2.3	3.1	3.3
1-1/2	4.0	2.6	6.3	2.1	3.4	6.3	8.0	2.6	3.7	4.0
2	5.0	3.3	8.2	2.6	4.5	8.2	10	3.3	4.7	5.0
2-1/2	6.0	4.1	10	3.2	5.2	10	12	4.1	5.6	6.0
3	7.5	5.0	12	4.0	6.4	12	15	5.0	7.0	7.5
3-1/2	9.0	5.9	15	4.7	7.3	15	18	5.9	8.0	9.0
4	10	6.7	17	5.2	8.5	17	21	6.7	9.0	10
5	13	8.2	21	6.5	11	21	25	8.2	12	13
6	16	10	25	7.9	13	25	30	10	14	16
8	20	13	---	10	---	33	40	13	18	20
10	25	16	---	13	---	42	50	16	23	25
12	30	19	---	16	---	50	60	19	26	30
14	34	23	---	18	---	55	68	23	30	34
16	38	26	---	20	---	62	78	26	35	38
18	42	29	---	23	---	70	85	29	40	42
20	50	33	---	26	---	81	100	33	44	50
24	60	40	---	30	---	94	115	40	50	60

* *R D approximately equal to 1.*

† *R D approximately equal to 1.5.*

Table 5c. Special Fitting Losses in Equivalent Feet of Pipe

Nom. Pipe or Tube Size In.	Sudden Enlargement* d/D			Sudden Contraction* d/D			Sharp Edge*		Pipe Projection*	
	1/4	1/2	3/4	1/4	1/2	3/4	Entrance	Exit	Entrance	Exit
										
3/8	1.4	0.8	0.3	0.7	0.5	0.3	1.5	0.8	1.5	1.1
1/2	1.8	1.1	0.4	0.9	0.7	0.4	1.8	1.0	1.8	1.5
3/4	2.5	1.5	0.5	1.2	1.0	0.5	2.8	1.4	2.8	2.2
1	3.2	2.0	0.7	1.6	1.2	0.7	3.7	1.8	3.7	2.7
1-1/4	4.7	3.0	1.0	2.3	1.8	1.0	5.3	2.6	5.3	4.2
1-1/2	5.8	3.6	1.2	2.9	2.2	1.2	6.6	3.3	6.6	5.0
2	8.0	4.8	1.6	4.0	3.0	1.6	9.0	4.4	9.0	6.8
2-1/2	10	6.1	2.0	5.0	3.8	2.0	12	5.6	12	8.7
3	13	8.0	2.6	6.5	4.9	2.6	14	7.2	14	11
3 1/2	15	9.2	3.0	7.7	6.0	3.0	17	8.5	17	13
4	17	11	3.8	9.0	6.8	3.8	20	10	20	16
5	24	15	5.0	12	9.0	5.0	27	14	27	20
6	29	22	6.0	15	11	6.0	33	19	33	25
8	---	25	8.5	---	15	8.5	47	24	47	35
10	---	32	11	---	20	11	60	29	60	46
12	---	41	13	---	25	13	73	37	73	57
14	---	---	16	---	---	16	86	45	86	66
16	---	---	18	---	---	18	96	50	96	77
18	---	---	20	---	---	20	115	58	115	90
20	---	---	---	---	---	---	142	70	142	108
24	---	---	---	---	---	---	163	83	163	130

* *Enter table for losses at smallest diameter d.*

TABLE 6a. FRICTION LOSS (ft. of head) FOR EQUIVALENT PIPE LENGTHS

		PIPE LENGTH, FT.										
Total Friction Loss (Ft.)	.1	12.5	10	8.3	7.1	6.25	5.5	5	4.5	4.2	3.8	3.6
	.2	25	20	16.6	14.3	12.5	11.1	10	8.1	8.3	7.7	7.2
	.3	37.5	30	25	21.4	18.7	16.6	15	13.6	12.5	11.6	10.7
	.4	50	40	33.3	28.6	25	22.2	20	18.2	16.6	15.3	14.3
	.5	62.5	50	41.6	35.7	31.2	27.7	25	22.7	20.8	19.2	17.9
	.6	75	60	50	42.8	37.4	33.2	30	27.2	25	23.2	21.4
	.7	87.5	70	58.3	50	43.7	38.8	35	31.8	29.1	26.9	25
	.8	100	80	66.6	57.2	50	44.4	40	36.4	33.2	30.6	28.6
	.9	112.5	90	75	64.3	56.2	50	45	40.9	37.4	34.5	32.1
	1.0	125	100	83.3	71.4	62.4	55.5	50	45.4	41.6	38.4	36.7
	1.1	137.5	110	91.3	78.5	68.6	60.9	55	49.9	45.8	42.4	39.2
	1.2	150	120	100	85.6	74.8	66.4	60	54.4	50	46.4	47.8
	1.3	162.5	130	108.3	92.8	81.1	72	65	59	54.1	50	46.4
	1.4	175	140	116.6	100	87.4	77.6	70	63.6	58.2	53.8	50
	1.5	187.5	150	125	107.2	93.7	83.2	75	68.2	62.3	57.5	53.6
	1.6	200	160	133.3	114.4	100	88.8	80	72.8	66.4	61.2	57.2
	1.7	212.5	170	141.6	121.5	106.2	94.4	85	77.3	70.6	65.1	60.7
	1.8	225	180	150	128.6	112.4	100	90	81.8	75	69	64.3
	1.9	237.5	190	158.3	135.7	118.6	105.5	95	86.3	79	72.9	67.9
	2.0	250	200	166.6	142.8	124.8	111	100	90.8	83.2	76.8	71.4
	2.1	262.5	210	175	150	131	116.4	105	95.3	87.4	80.8	75
	2.2	275	220	183.3	157.1	137.2	121.8	110	100	91.6	84.8	78.6
	2.3	287.5	230	191.3	164.1	143.4	127.3	115	104.3	95.8	88.8	82
	2.4	300	240	200	171.2	149.6	132.8	120	108.3	100	92.8	85.6
	2.5	312.5	250	208.3	178.4	155.9	138.4	125	113.4	104.1	96.4	89.2
	2.6	325	260	216.6	185.6	162.2	144	130	118	108.2	100	92.8
	2.7	337.5	270	225	192.8	168.5	149.6	135	122.6	112.3	103.8	96.4
	2.8	350	280	233.3	200	174.8	155.2	140	127.2	116.4	107.6	100
	2.9	362.5	290	241.6	207.2	181.1	160.8	145	131.8	120.5	111.3	103.6
	3.0	375	300	250	214.4	187.4	166.4	150	136.4	124.6	115	107.2
	3.2	400	320	258.3	228.8	200	177.6	160	145.6	132.8	122.4	114.4
	3.4	425	340	283.2	250	212.4	188.8	170	154.6	141.2	130.4	125
	3.6	450	360	300	257.2	224.8	200	180	163.6	150	138	128.6
	3.8	475	380	316	271.4	237.2	211	190	172.6	158	145.8	135.7
	4.0	500	400	333	285.6	249.6	222	200	181.6	166.4	153.6	142.8
	4.2	525	420	350	300	262	232.4	210	190.6	174.8	161.6	150
	4.4	550	440	366	314.2	274.4	243.6	220	200	183.2	169.6	157.1
	4.6	575	460	379	328.2	286.8	254.6	230	208.6	191.6	177.6	164.1
	4.8	600	480	400	342.4	289.2	265.6	240	217.6	200	185.6	171.2
	5.0	625	500	416	357	312	278	250	226.8	208.2	192.8	178.5
Friction Loss Rate: ft./100'		.8	1.0	1.2	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8
		GPM										
Nominal Pipe Size	3/8	--	.46	.51	.55	.6	.63	.67	.7	.74	.76	.8
	1/2	.76	.86	.95	1.07	1.12	1.2	1.27	1.33	1.4	1.46	1.52
	3/4	1.62	1.85	2	2.2	2.4	2.55	2.7	2.85	2.95	3.1	3.22
	1	3.1	3.5	3.9	4.3	4.55	4.8	5.2	5.4	5.7	5.9	6.2
	1-1/4	6.6	7.2	8.2	8.8	9.6	10.5	10.75	11.2	11.8	12.5	13
	1-1/2	9.8	11.1	12.2	13.3	14.2	15.1	16	17	17.8	18.5	19.2
	2	19.2	21.5	24	26	28	29.8	31.5	33	34.5	36	37.5
	2-1/2	30.5	35	38	42	44	47	50	53	56	58	60
	3	55	63	69	75	80	85	90	95	100	105	110
	4	115	128	142	153	165	175	188	198	208	215	224
	5	208	232	258	280	300	320	340	360	378	390	408
	6	335	380	420	450	490	520	550	580	610	640	670
	8	700	780	820	940	1000	1090	1130	1200	1280	1310	1370
	10	1260	1410	1580	1700	1810	1950	2060	2160	2290	2390	2500
	12	2000	2250	2500	2700	2900	3100	3300	3400	3600	3700	3900
Copper Tube Nominal (I.D. Size) "Type L"	3/8	--	--	--	--	.4	.43	.45	.48	.5	.52	.55
	1/2	--	--	.64	.7	.75	.8	.85	.9	.95	1.0	1.2
	5/8	.9	1.0	1.15	1.25	1.34	1.42	1.5	1.6	1.68	1.75	1.82
	3/4	1.4	1.6	1.75	1.9	2.05	2.2	2.3	2.45	2.55	2.65	2.8
	1	3.0	3.4	3.7	4.1	4.4	4.7	5.0	5.2	5.5	5.7	6.0
	1-1/4	5.2	5.9	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5
	1-1/2	8.5	9.5	10.0	10.5	11.2	13.0	13.8	14.5	15.0	15.8	16.5
	2	18.0	20.0	22.0	24.0	26.0	28.0	30.0	31.0	33.0	34.0	35.5
	2-1/2	32.0	36.5	40.0	44.0	47.0	50.0	52.5	55.5	58.0	62.0	64.0
	3	51.0	57.0	63.0	70.0	74.0	79.0	83.0	88.0	93.0	97.0	100

TABLE 6a. FRICTION LOSS (ft. of head) FOR EQUIVALENT PIPE LENGTHS

PIPE LENGTH, FT.												
3.3	3.1	2.9	2.7	2.6	2.5	2.4	2.3	2.2	2.1	2	.1	Total Friction Loss (Ft.)
6.6	6.2	5.9	5.5	5.2	5	4.7	4.5	4.3	4.1	4	.2	
10	9.3	8.8	8.3	7.9	7.5	7.1	6.8	6.5	6.2	6	.3	
13.3	12.5	11.7	11.1	10.5	10	9.5	9.0	8.7	8.3	8	.4	
16.6	15.6	14.7	13.8	13.1	12.5	11.9	11.3	10.8	10.4	10	.5	
20	18.7	17.6	16.6	15.7	15	14.3	13.6	13	12.5	12	.6	
23.3	21.8	20.5	19.4	18.4	17.5	16.7	15.9	15.2	14.6	14	.7	
26.6	25	23.4	22.2	21	20	19	18.2	17.4	16.6	16	.8	
30	28.1	26.4	25	23.6	22.5	21.4	20.7	19.5	18.7	18	.9	
33.3	31.2	29.4	27.7	26.2	25	23.8	22.3	21.6	20.8	20	1.0	
36.6	34.3	32.3	30.4	28.9	27.5	26.2	24.9	23.8	22.9	22	1.1	
40	37.8	35.2	33.2	31.4	30	28.6	27.2	26	25	24	1.2	
43.3	40.6	38.1	36	34.1	32.5	31	29.5	28.2	27	26	1.3	
46.6	43.7	41	38.8	36.8	35	33.4	31.8	30.4	29.1	28	1.4	
50	46.9	43.9	41.6	39.4	37.5	35.7	34.1	32.6	31.1	30	1.5	
53.3	50	46.8	44.4	42	40	38	36.4	34.8	33.2	32	1.6	
56.6	53.1	50	47.2	44.6	42.5	40.4	38.7	36.9	35.3	34	1.7	
60	56.2	52.8	50	47.2	45	42.4	40.9	39	37.5	36	1.8	
63.3	59.3	55.8	52.7	50	47.5	45.2	43.1	41.1	39.5	38	1.9	
66.6	62.4	58.8	55.5	52.4	50	47.6	45.4	43.2	41.6	40	2.0	
70	65.5	61.7	58.7	55.1	52.5	50	47.7	45.4	43.7	42	2.1	
73.3	68.6	64.6	60.9	57.8	55	52.4	50	47.6	45.8	44	2.2	
76.6	71.7	67.5	63.6	60.3	57.5	54.8	52.1	50	47.9	46	2.3	
80	74.8	70.4	66.4	62.8	60	57.2	54.4	52	50	48	2.4	
83.3	77.9	73.3	69.2	65.5	62.5	59.6	56.7	54.2	52	50	2.5	
86.6	81.1	76.2	72	68.2	65	62	59	56.4	54.1	52	2.6	
90	84.3	79.1	74.8	70.9	67.5	64.4	61.3	58.6	56.1	54	2.7	
93.3	87.4	82	77.6	73.6	70	66.8	63.6	60.4	58.2	56	2.8	
96.6	90.5	84.9	80.4	76.2	72.5	69.1	65.9	63	60.2	58	2.9	
100	93.7	87.8	83.2	78.8	75	71.4	68.2	65.2	62.3	60	3.0	
106.6	100	93.6	88.8	84	80	73.7	72.8	67.4	66.4	64	3.2	
113.2	106.2	100	94.4	89.2	85	80.8	77.3	73.8	70.6	68	3.4	
120	112.4	105.6	100	94.4	90	84.8	81.6	78	75	72	3.6	
126.6	118.6	111.6	105.5	100	95	90.4	86.3	82.2	79	76	3.8	
133.2	124.8	117.6	111	104.8	100	95.2	90.8	86.4	83.2	80	4.0	
140	131	123.4	116.2	110.2	105	100	95.3	90.8	87.4	84	4.2	
146.6	137.2	129.2	121.8	115.6	110	104.8	100	95.2	91.6	88	4.4	
153.2	143.4	135	127.3	120.6	115	109.6	104.3	100	95.8	92	4.6	
160	150	140.8	132.8	125.6	120	114.4	108.8	104	100	96	4.8	
166.6	156	146.6	139	131	125	119.2	113.4	108.4	104.1	100	5.0	
3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0		Friction Loss Rate; ft./100'
GPM												
.84	.86	.89	.92	.95	.97	1	1.02	1.05	1.07	1.1	3/8	Nominal Pipe Size
1.59	1.62	1.68	1.75	1.8	1.85	1.9	1.95	2	2.04	2.08	1/2	
3.35	3.5	3.6	3.7	3.8	3.9	4	4.1	4.2	4.3	4.4	3/4	
6.4	6.6	6.9	7.1	7.3	7.5	7.7	7.9	8.1	8.3	8.4	1	
13.4	13.8	14.2	14.8	15	15.5	16	16.4	16.8	17.2	17.5	1-1/4	
20	20.8	21.4	22	22.8	23.6	24.2	24.8	25.4	26	26.5	1-1/2	
39	40.5	42	43	44	45	46	47	48	50	51	2	
62.5	65	67	69	71	73	75	77	78	80	82	2-1/2	
114	118	122	126	128	132	136	139	142	146	150	3	
233	242	250	257	265	270	278	286	296	302	306	4	
425	440	455	468	481	495	505	520	535	550	560	5	
700	720	750	770	800	820	840	860	880	900	920	6	
1420	1490	1530	1580	1630	1680	1730	1760	1800	1850	1900	8	
2600	2700	2750	2850	2930	3000	3100	3200	3250	3300	3400	10	
4100	4200	4350	4500	4650	4800	4950	5100	5250	5400	5500	12	
.57	.59	.61	.63	.65	.67	.68	.7	.72	.74	.75	3/8	Copper Tube Nominal (I.D. Sizes) "Type L"
1.4	1.6	1.13	1.17	1.2	1.2	1.25	1.3	1.35	1.38	1.4	1/2	
1.9	1.95	2.0	2.07	2.15	2.2	2.25	2.3	2.35	2.4	2.45	5/8	
2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3/4	
6.2	6.5	6.8	7.0	7.2	7.5	7.7	8.0	8.2	8.3	8.5	1	
11.0	11.5	11.2	11.8	12.1	12.5	12.9	13.3	13.6	13.8	14.0	1-1/4	
17.2	18.0	18.4	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5	1-1/2	
37.0	38.0	39.0	41.0	42.0	43.0	44.0	45.0	46.0	47.0	48.0	2	
66.0	68.0	68.0	70.0	72.0	74.0	76.0	78.0	80.0	82.0	84.0	2-1/2	
106.0	110.0	116.0	120.0	124.0	128.0	130	132.0	135.0	139.0	142	3	

TABLE 6b. STRAINER FRICTION LOSS

FRICTION LOSS FOR TYPICAL STRAINER

PIPE SIZE: 3/4" nominal		PIPE SIZE: 1" nominal		PIPE SIZE: 1-1/4" nominal	
GPM	FRICTION LOSS (ft. of head)*	GPM	FRICTION LOSS (ft. of head)	GPM	FRICTION LOSS (ft. of head)
10	1.26	10	.46	10	.23
15	2.88	15	.92	15	.46
20	5.18	20	1.84	20	.92

TABLE 6c. 3-WAY VALVE FRICTION LOSS

FRICTION LOSS FOR TYPICAL 3-WAY VALVE

Approx. Orifice Size (in.)	Approx. Cv	Approx. Orifice Size (in.)	Approx. Cv	Approx. Orifice Size (in.)	Approx. Cv	Approx. Orifice Size (in.)	Approx. Cv
1/32	.02	9/64	.36	1/2	3.5	1-1/4	17
3/64	.06	3/16	.53	5/8	4.5	1-1/2	25
1/16	.09	1/4	.70	11/16	5	2	48
3/32	.20	5/16	1.7	3/4	7.5	2-1/2	60
1/8	.30	3/8	2	1	13	3	100

NOTE: Use Conversion Chart on next page to convert Cv to friction loss in ft. of head. It may be more economical to select a smaller, cheaper 3-way valve than to select one that matches the pipe size. A smaller 3-way valve has a lesser Cv and more friction loss than a larger valve. A general rule is to select a valve with a friction loss under 3 ft. of head.

Cv CONVERSION CHART FOR TABLE 6c.

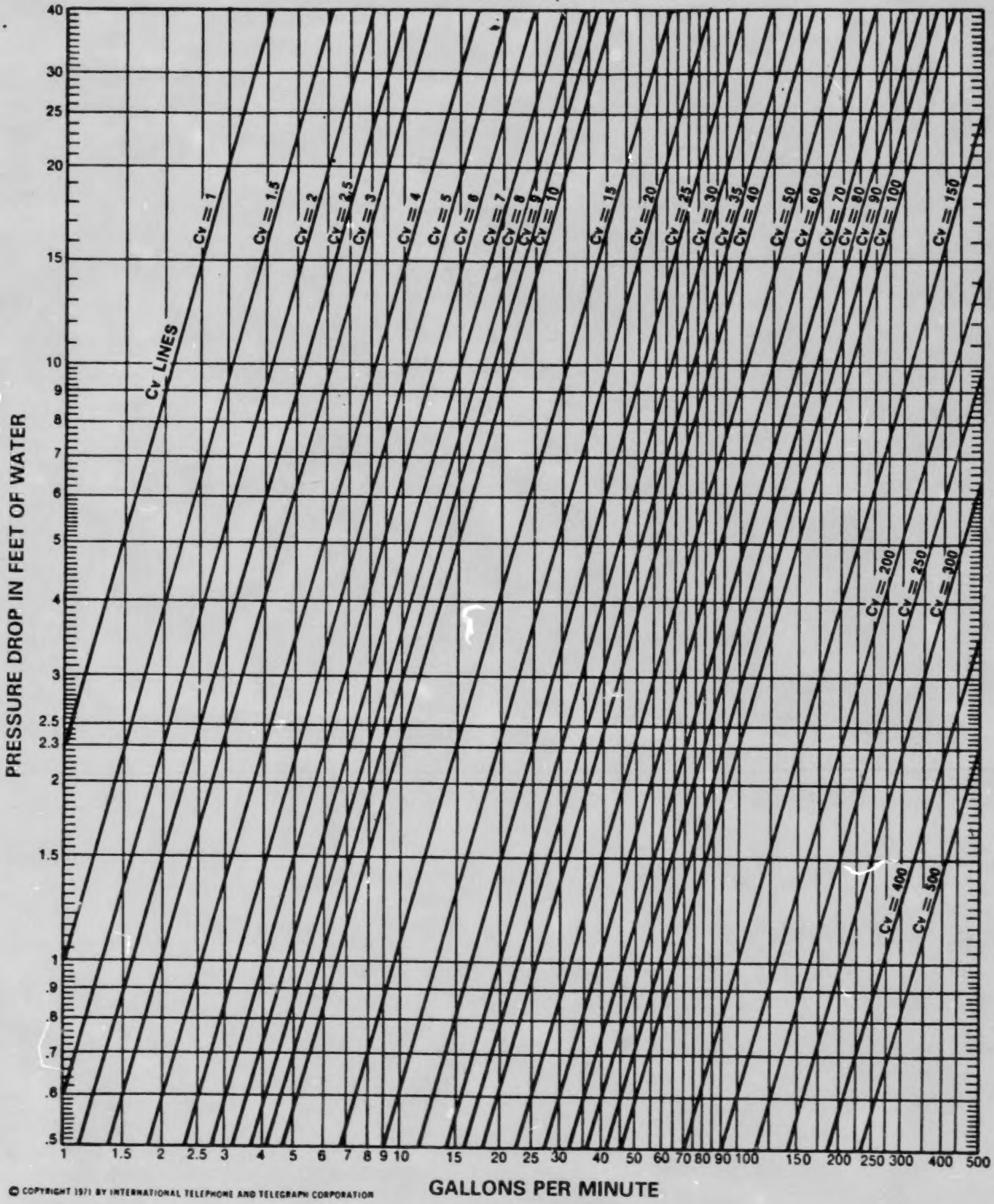


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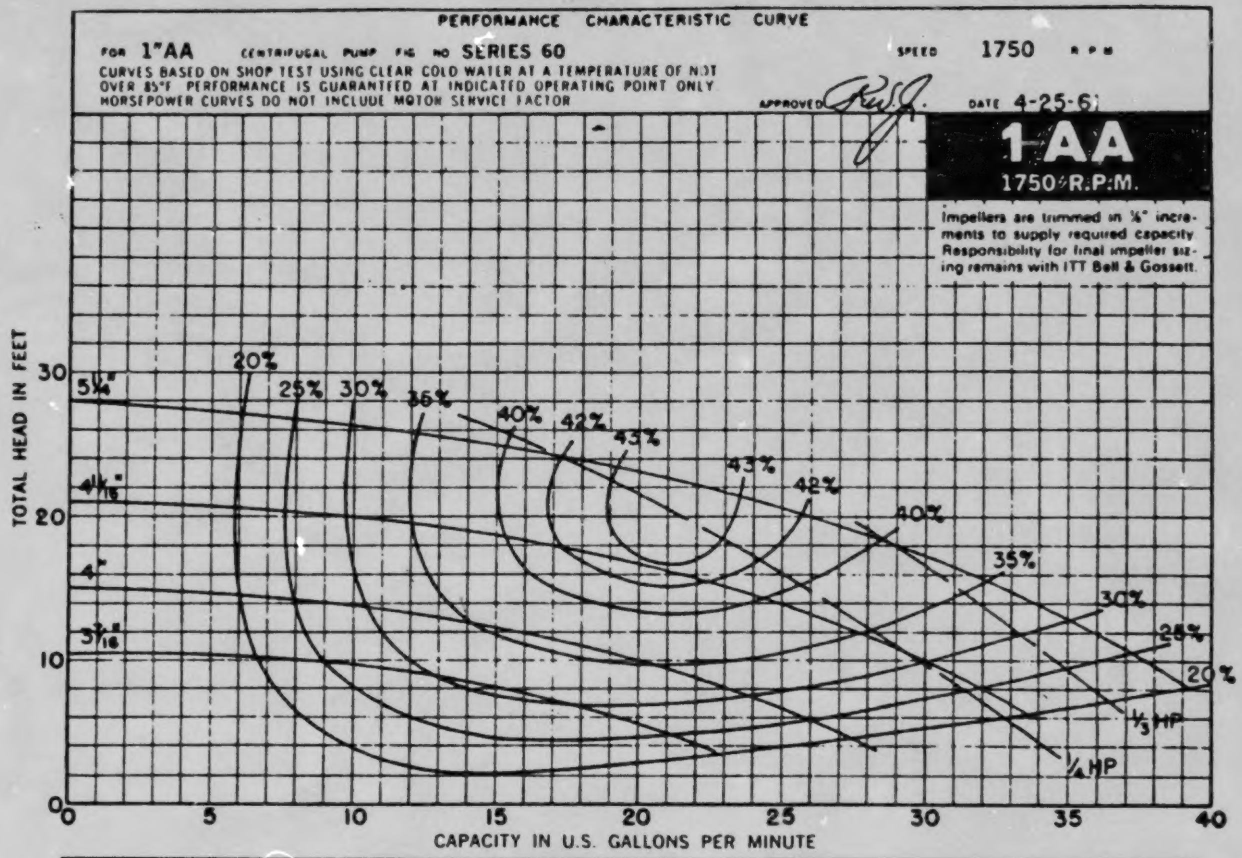
TABLE 7a. PUMP PERFORMANCE CURVES — ITT BELL & GOSSETT

V-255



PERFORMANCE CHARACTERISTIC CURVE

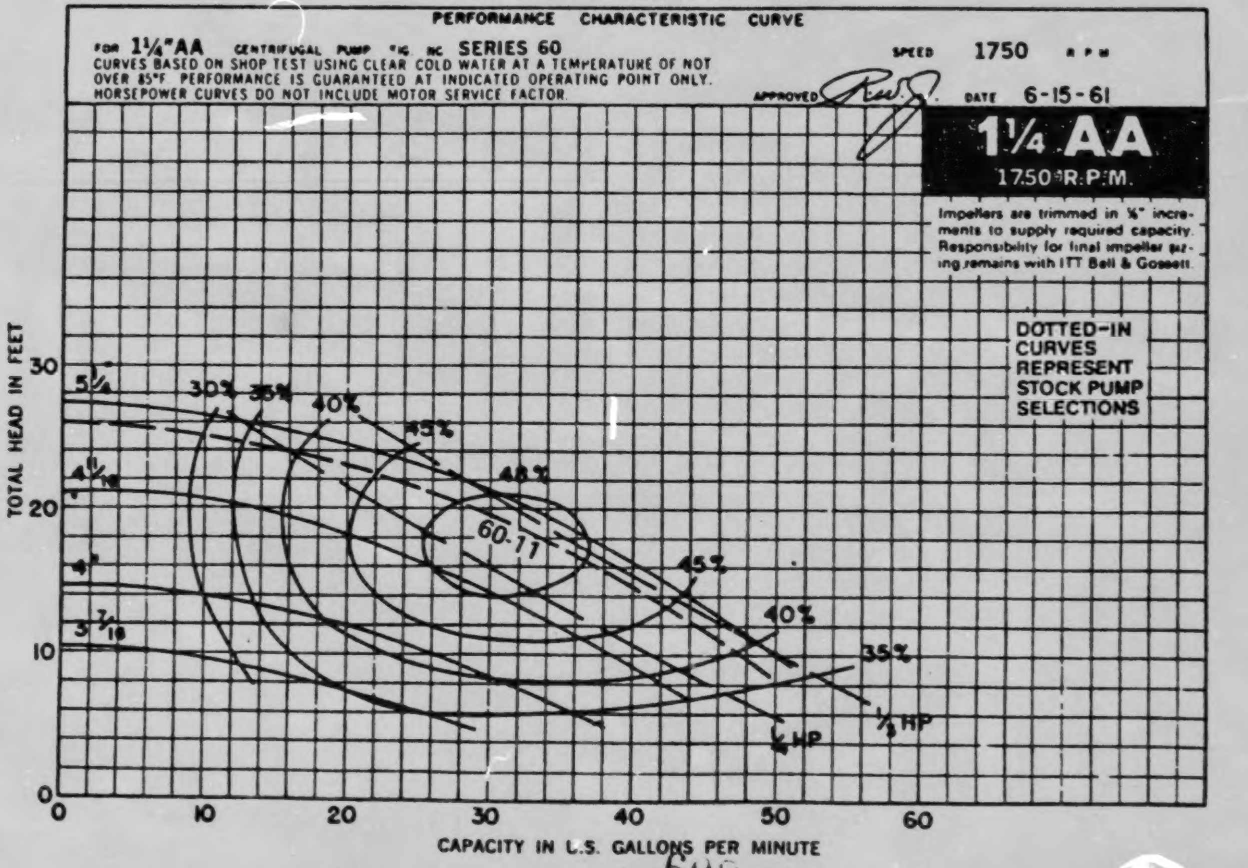
FOR 1"AA CENTRIFUGAL PUMP FIG. NO SERIES 60 SPEED 1750 RPM

CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

APPROVED DATE 4-25-61

1 AA
1750 R.P.M.

Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.



PERFORMANCE CHARACTERISTIC CURVE

FOR 1¼"AA CENTRIFUGAL PUMP FIG. NO SERIES 60 SPEED 1750 RPM

CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

APPROVED DATE 6-15-61

1¼ AA
1750 R.P.M.

Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

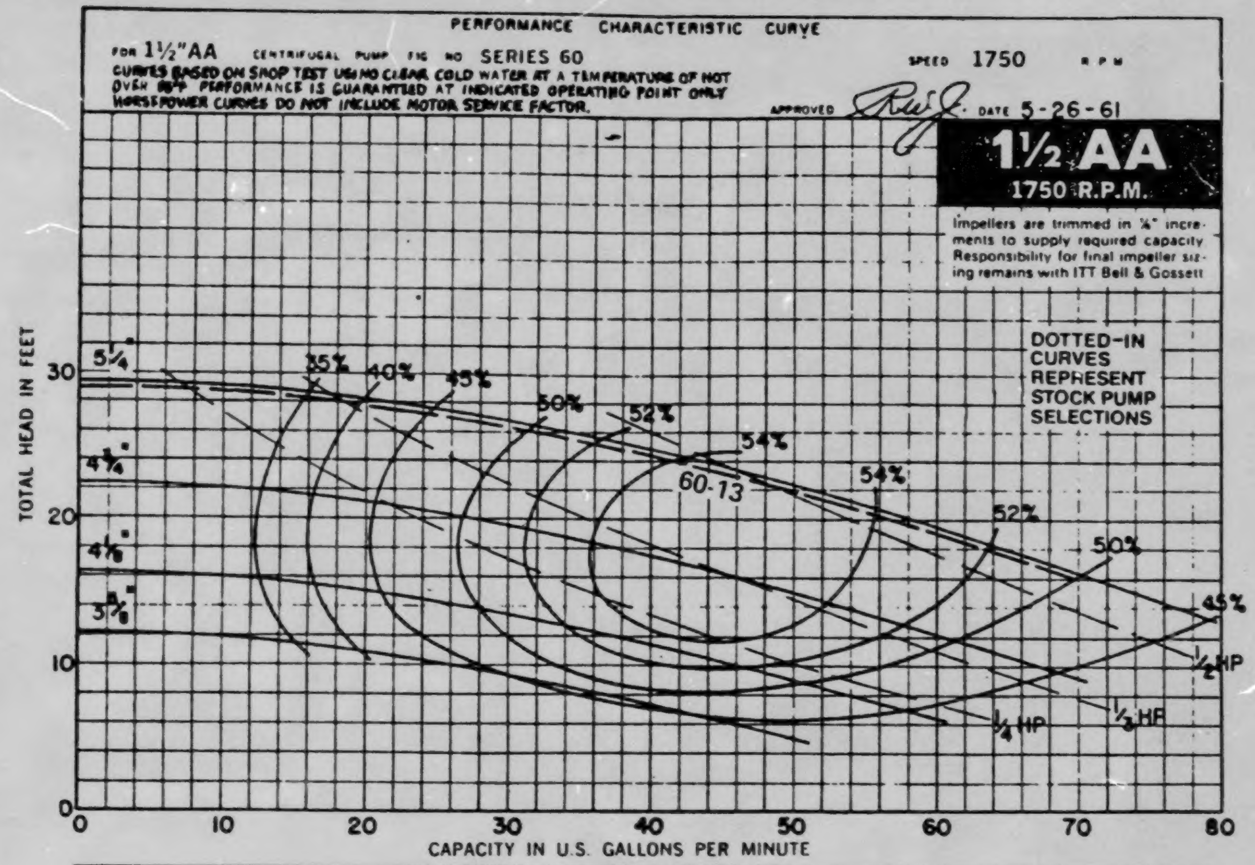
DOTTED-IN CURVES REPRESENT STOCK PUMP SELECTIONS

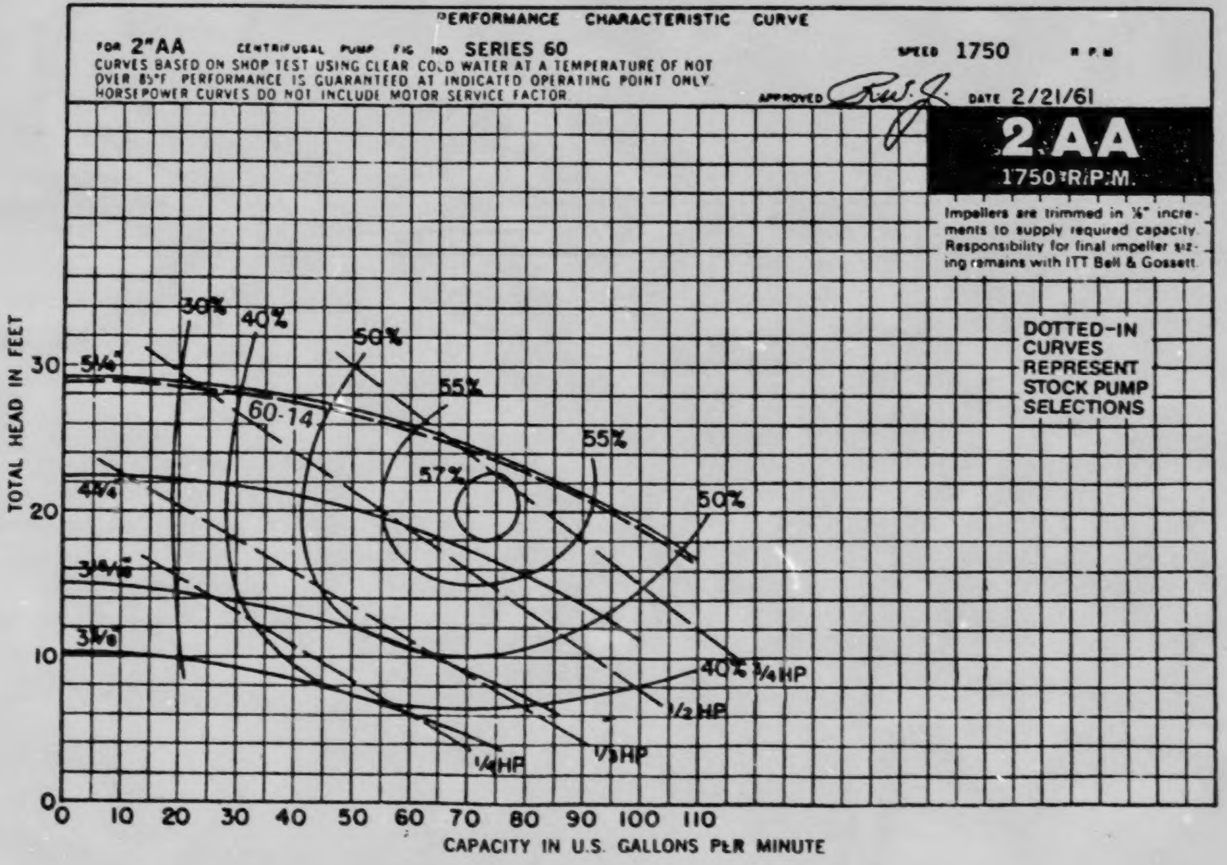
TOTAL HEAD IN FEET
0
10
20
30
5¼
4 11/16
4"
3 7/16
30%
35%
40%
45%
48%
60-11
45%
40%
35%
⅓ HP
¼ HP
0
10
20
30
40
50
60
CAPACITY IN U.S. GALLONS PER MINUTE

TABLES 7a. PUMP PERFORMANCE CURVES — ITT BELL & GOSSETT

V-256

7





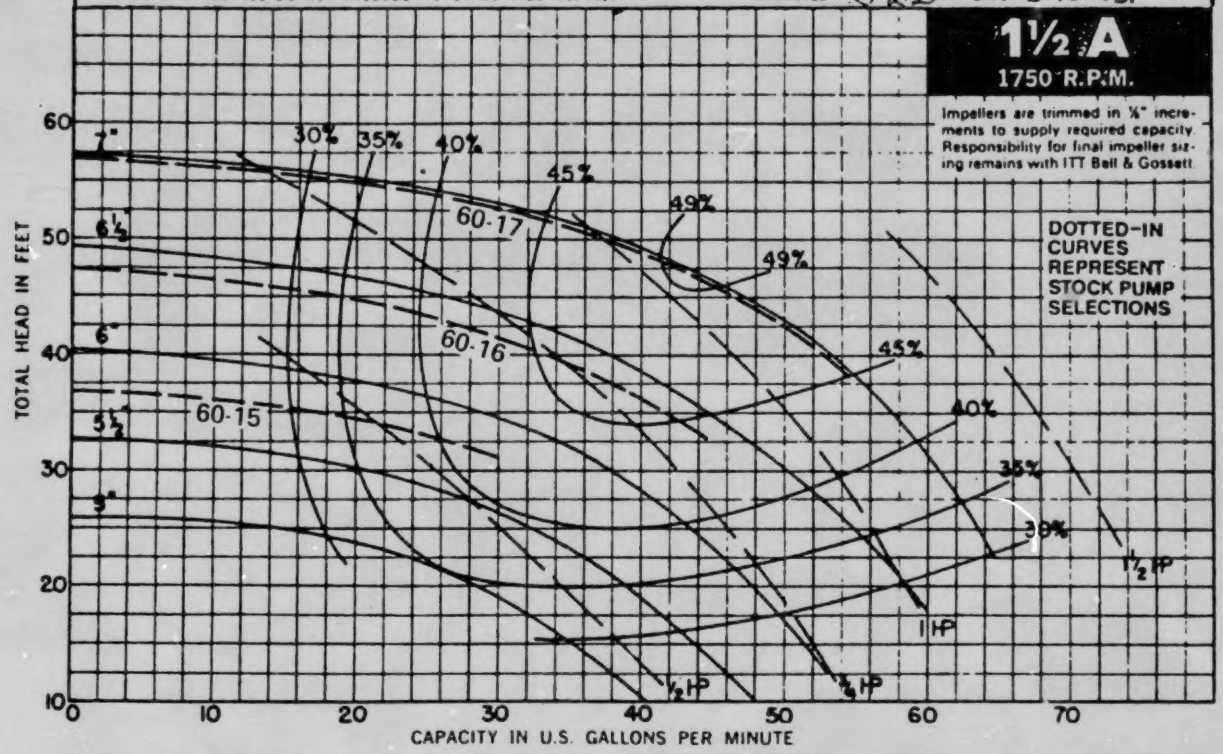
TABLES 7a. PUMP PERFORMANCE CURVES — ITT BELL & GOSSETT

PERFORMANCE CHARACTERISTIC CURVE

FOR 1½"A CENTRIFUGAL PUMP FIG. NO. SERIES 60 SPEED 1750 R.P.M.

CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

APPROVED GLD DATE 3-19-63.



Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

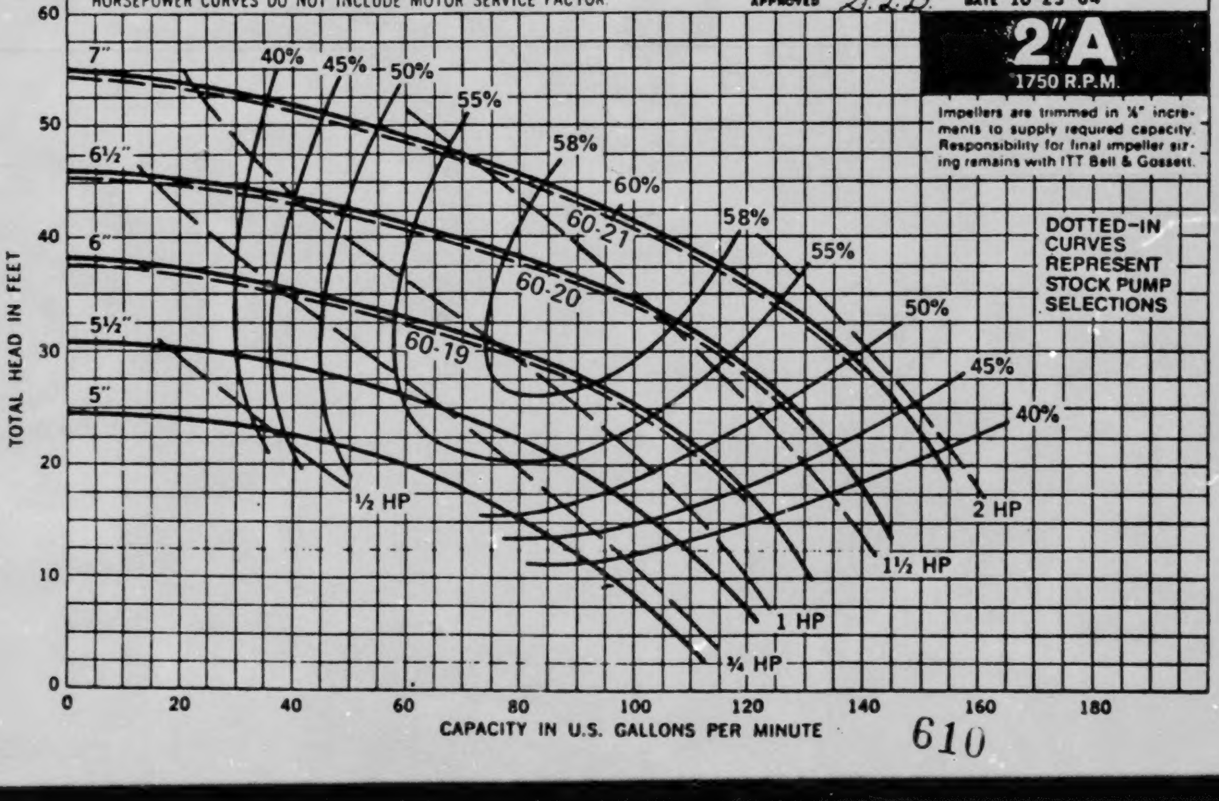
DOTTED-IN CURVES REPRESENT STOCK PUMP SELECTIONS

PERFORMANCE CHARACTERISTIC CURVE

FOR 2"A CENTRIFUGAL PUMP FIG. NO. SERIES 60 SPEED 1750 R.P.M.

CURVES BASED ON SHOP TEST USING CLEAR COLD WATER AT A TEMPERATURE OF NOT OVER 85°F. PERFORMANCE IS GUARANTEED AT INDICATED OPERATING POINT ONLY. HORSEPOWER CURVES DO NOT INCLUDE MOTOR SERVICE FACTOR.

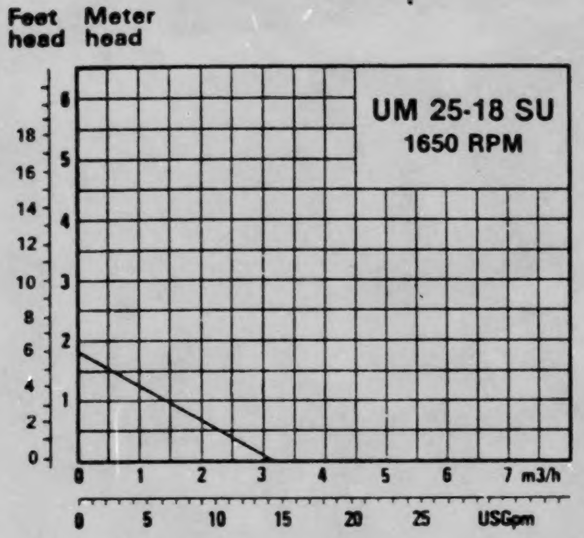
APPROVED GLD DATE 10-23-64

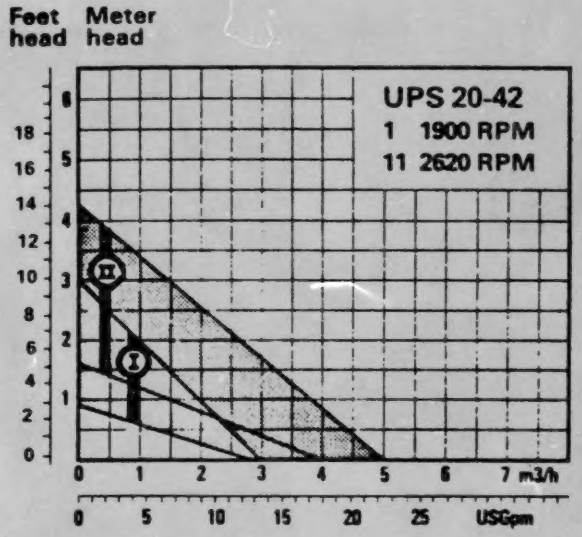


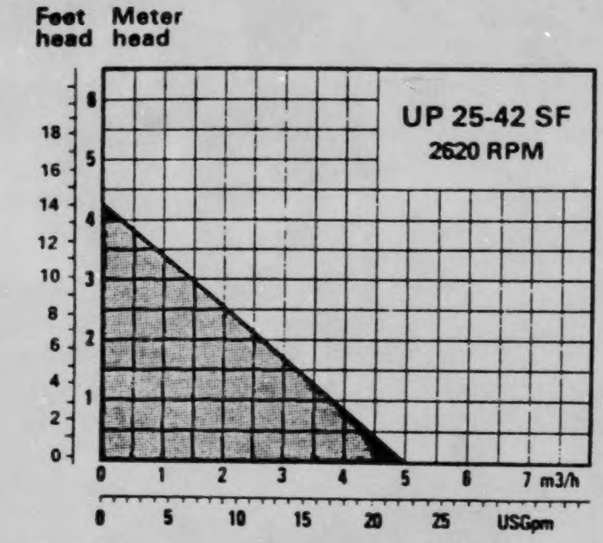
Impellers are trimmed in ⅛" increments to supply required capacity. Responsibility for final impeller sizing remains with ITT Bell & Gossett.

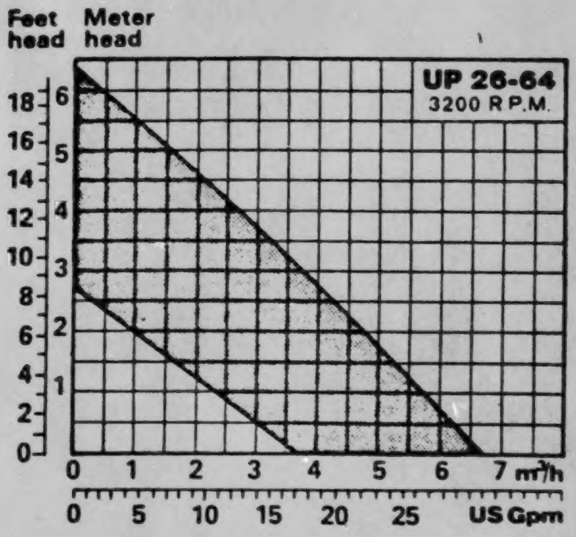
DOTTED-IN CURVES REPRESENT STOCK PUMP SELECTIONS

TABLE 7b. PUMP PERFORMANCE CURVES — GRUNDFOS









TABLES 8a, 8b & 8c. COMPRESSION TANK SELECTION DATA

TABLE 8a. WATER VOLUME PER FEET OF PIPE

PIPE DIAMETER	GAL. PER LINEAR FT.	PIPE DIAMETER	GAL PER LINEAR FT.
3/8"	.007		
1/2"	.016	3"	.38
3/4"	.028	4"	.66
1"	.045	5"	1.04
1-1/4"	.078	6"	1.5
1-1/2"	.106	8"	2.66
2"	.17	10"	4.2
2-1/2"	.25	12"	5.96

TABLE 8b. COMPRESSION TANK CAPACITY REQUIREMENTS

WATER VOLUME IN GALS.	TANK CAPACITY REQUIREMENTS						
	MEAN DESIGN WATER TEMPERATURE °F						
	150°	160°	180°	200°	220°	240°	250°
10	0.6	0.8	1.0	1.3	1.6	1.9	2.0
20	1.2	1.7	2.0	2.6	3.2	3.8	4.1
30	1.8	2.5	3.0	4.0	4.8	5.7	6.1
40	2.4	3.3	4.0	5.3	6.4	7.6	8.2
50	3.0	4.2	5.0	6.6	8.0	9.5	10
60	3.6	5.0	6.0	7.9	9.7	11	12
70	4.2	5.8	7.0	9.2	11	13	14
80	4.7	6.7	8.0	11	13	15	16
90	5.3	7.5	9.0	12	14	17	18
100	5.9	8.0	10	13	15	19	20

*Compression tanks are ITT Bell & Gossett models. Selection based on Tank equipped with Airtrol Tank Fitting 12 psig initial fill pressure, —30 psi relief valve setting.

TABLE 8c. COMPRESSION TANK SELECTION & SPECIFICATIONS

(For Sizes Not Shown, Use Multiple Tanks or Write to Factory for Quotation)

ASME CONSTRUCTION

Tank* Number	Capacity In. Gal.	Dimensions	1/3' MPT Gauge Glass Ctr-Ctr	Airtrol Tank Fitting	Tank Tapping	Approx. Shipping Weigh
15	15	13' x 34-1/2'	7-1/2'	ATF-12	2 - 1/2'	69
24	24	13' x 51'	7-1/2'	ATF-12	2 - 1/2'	90
30	30	13' x 61-1/2'	7-1/2'	ATF-12	2 - 1/2'	104
40	40	16-1/4' x 53'	10'	ATF-16	2 - 1/2'	122
60	60	16-1/4' x 76-1/2'	10'	ATF-16	2 - 1/2'	160
80	80	20-1/2' x 63'	14'	ATF-18	1/2' + 1'	203
100	100	20-1/2' x 82'	14'	ATFL-1'	1/2' + 1'	234
120	120	24-1/4' x 71-1/2'	18'	ATFL-1'	1/2' + 1'	283
144	144	24-1/4' x 83-1/2'	18'	ATFL-1'	1/2' + 1'	319
163	163	30' x 60'	24'	ATFL-1'	1/2' + 1'	375
202	202	30' x 72'	24'	ATFL-1'	1/2' + 1'	485
238	238	36' x 84'	24'	ATFL-1'	1/2' + 1'	495
270	270	30' x 56'	24'	ATFL-1'	1/2' + 1'	680
306	306	30' x 108'	24'	ATFL-1'	1/2' + 1'	760
337	337	36' x 84'	30'	ATFL-1'	1/2' + 1'	705
383	383	36' x 96'	30'	ATFL-1'	1/2' + 1'	805

*Compression tanks are ITT Bell & Gossett models. When ordering, specify ASME Construction on the order. Gauge glass tappings furnished on all ASME tanks as standard equipment. All welding to conform to paragraph U-W rules for construction of unlined vessels. Section VIII of the ASME Builder Construction Code: Test Pressure — 250 PSI; Working Pressure — 125 PSI; Max. Temp. — 375°F. 125 P.S.I.G. Working Pressure — 375°F Maximum Operating Temperature.

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 13: Air Transport System V-263

After the array size has been chosen and placed on the drawing, the storage unit and heat exchanger selected and located, it is time to select duct sizes and blower requirements.

Using NESCA Manual D and Air Handler specification sheets:

1. Determine the air flow requirements based upon $2CFM/ft^2$ collector array.
2. Select the required duct sizes for the collector to storage loop.
3. Select the Air Handler Unit.

NOTE: Solaron's Application Engineering Manual, Section 800 will be very helpful in completing this lab.

LAB: SYSTEM SIZING, DESIGN AND RETROFIT

Lab 14: Size and Select Total System-New Construction V-265

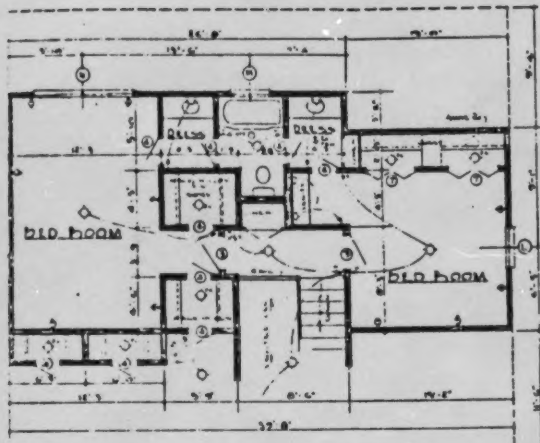
You now have developed skills in each area of system sizing - collectors, storage, heat exchangers, piping/ducts, and pumps/blowers. This lab will aid in developing the ability to perform this task as a whole, rather than pieces.

Using the floor plan provided and information as to wall construction, insulation, colors, floor and ceiling construction, etc. provided by the lab attendant:

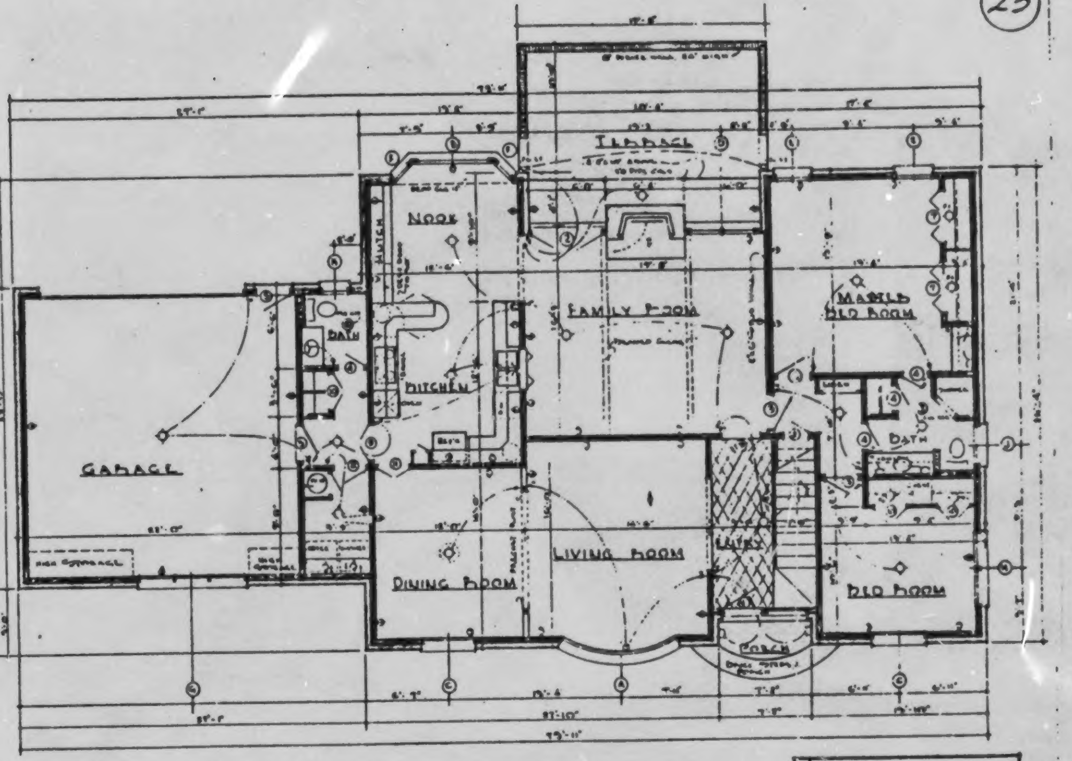
1. Complete a load calculation for space heating, cooling and DHW.
2. Design a solar system for this house that will provide a heating solar fraction (annual) of 60-7014. Use the same forms and procedures used in Labs 9-13.

LAB: SYSTEM SIZING, DESIGN AND RETROFIT V-267

(23)


BED ROOM
DRESS
DRESS
BED ROOM

SECOND FLOOR PLAN


TERRACE
NOOK
HUTCH
KITCHEN
BATH
FAMILY ROOM
MASTER BED ROOM
BATH
GARAGE
DINING ROOM
LIVING ROOM
ENTRY
PORCH
BED ROOM
79'-11"

FIRST FLOOR PLAN

DOORS		
1	[illegible]	SPECIAL
2	[illegible]	15LT FRENCH
3	[illegible]	
4	[illegible]	
5	[illegible]	[illegible]
6	[illegible]	[illegible]
7	[illegible]	[illegible]
8	[illegible]	
9	[illegible]	
10	[illegible]	
11	[illegible]	
12	[illegible]	

WINDOWS (ALUM)		
A	[illegible]	[illegible]
B	[illegible]	[illegible]
C	[illegible]	[illegible]
D	[illegible]	[illegible]
E	[illegible]	[illegible]
F	[illegible]	[illegible]
G	[illegible]	[illegible]
H	[illegible]	[illegible]
J	[illegible]	[illegible]
K	[illegible]	[illegible]
L	[illegible]	[illegible]
M	[illegible]	[illegible]
N	[illegible]	[illegible]

AREAS	
FIRST FLOOR	1074 SQ FT
SECOND FLOOR	706 " "
[illegible] TOTAL	1910 " "
TERRACE	271 " "
PORCH	51 " "
GARAGE	576 " "

THE PLAN SHOPPE
[illegible]
DALLAS, TEXAS
DESIGN NO [illegible]
DATE

615

616

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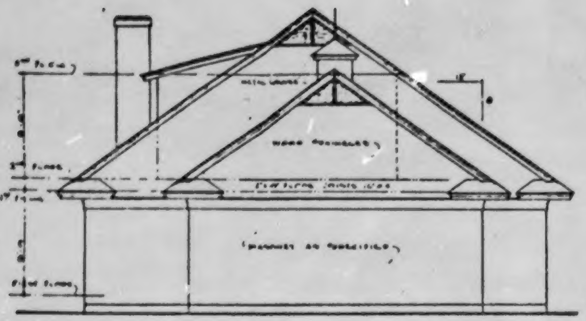
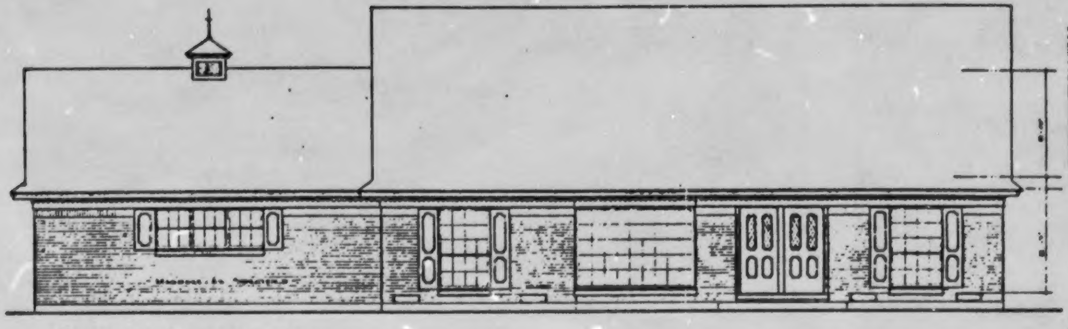
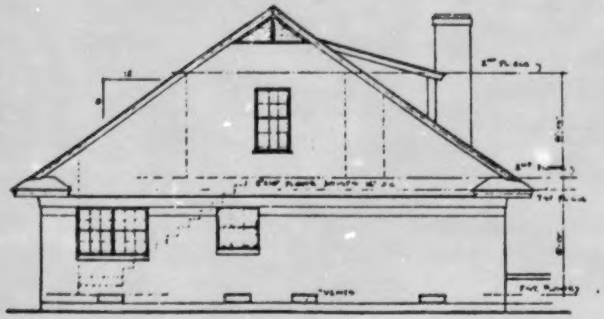


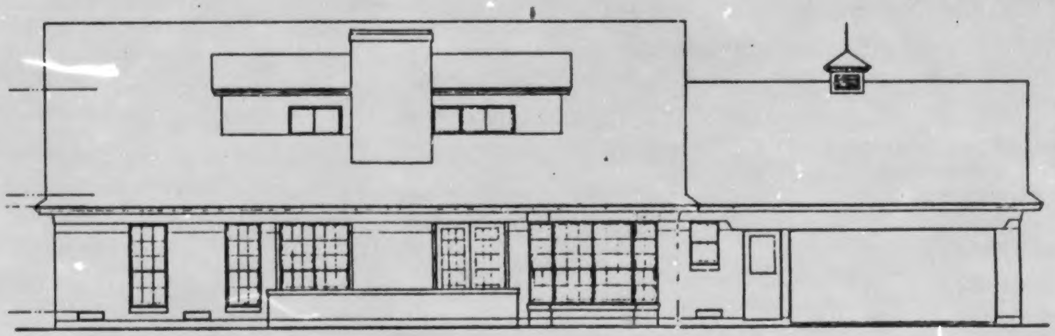
LEFT ELEVATION



FRONT ELEVATION



RIGHT ELEVATION



REAR ELEVATION

LAB: SYSTEM SIZING, DESIGN AND RETROFIT V-269

THE PLAN SHOPPE
DALLAS, TEXAS

DRAWN BY
DATE

Lab 15: Size and Select Total System - Retrofit V-271

Design and installation of solar systems on existing structures is a major challenge. Many limiting factors: i.e. where can storage be placed, can existing ducts be used, is orientation acceptable, will the roof need rebuilding, etc., are all questions that must be answered.

Select an existing residential **structure** that may be **receptive** to solarization and:

1. Draw a sketch of the floor plan and elevations.

2. Complete a load calculation for space heating and DHW.

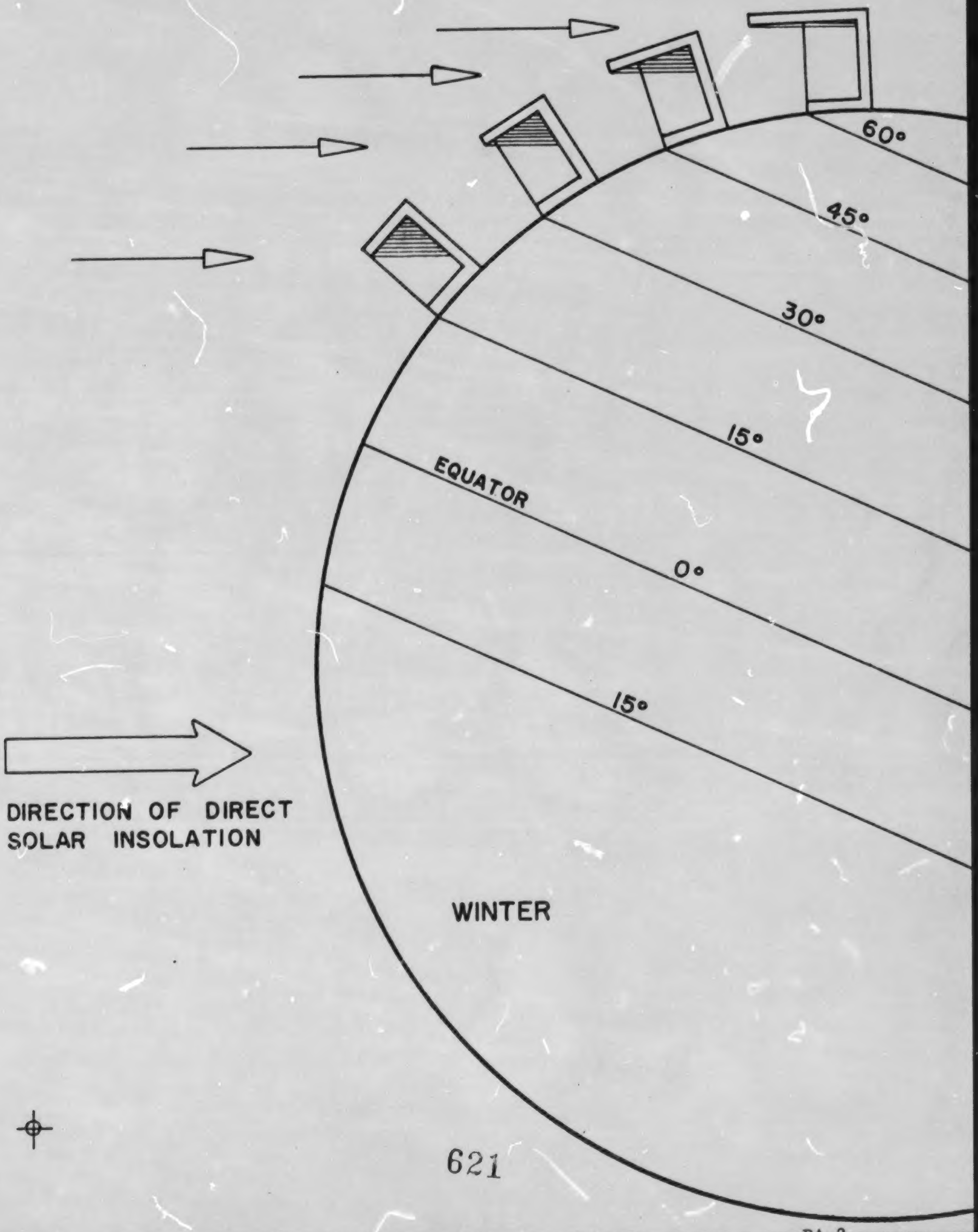
3. Design a system that is economically practical for this retrofit application.

SYSTEM SIZING, DESIGN AND RETROFIT

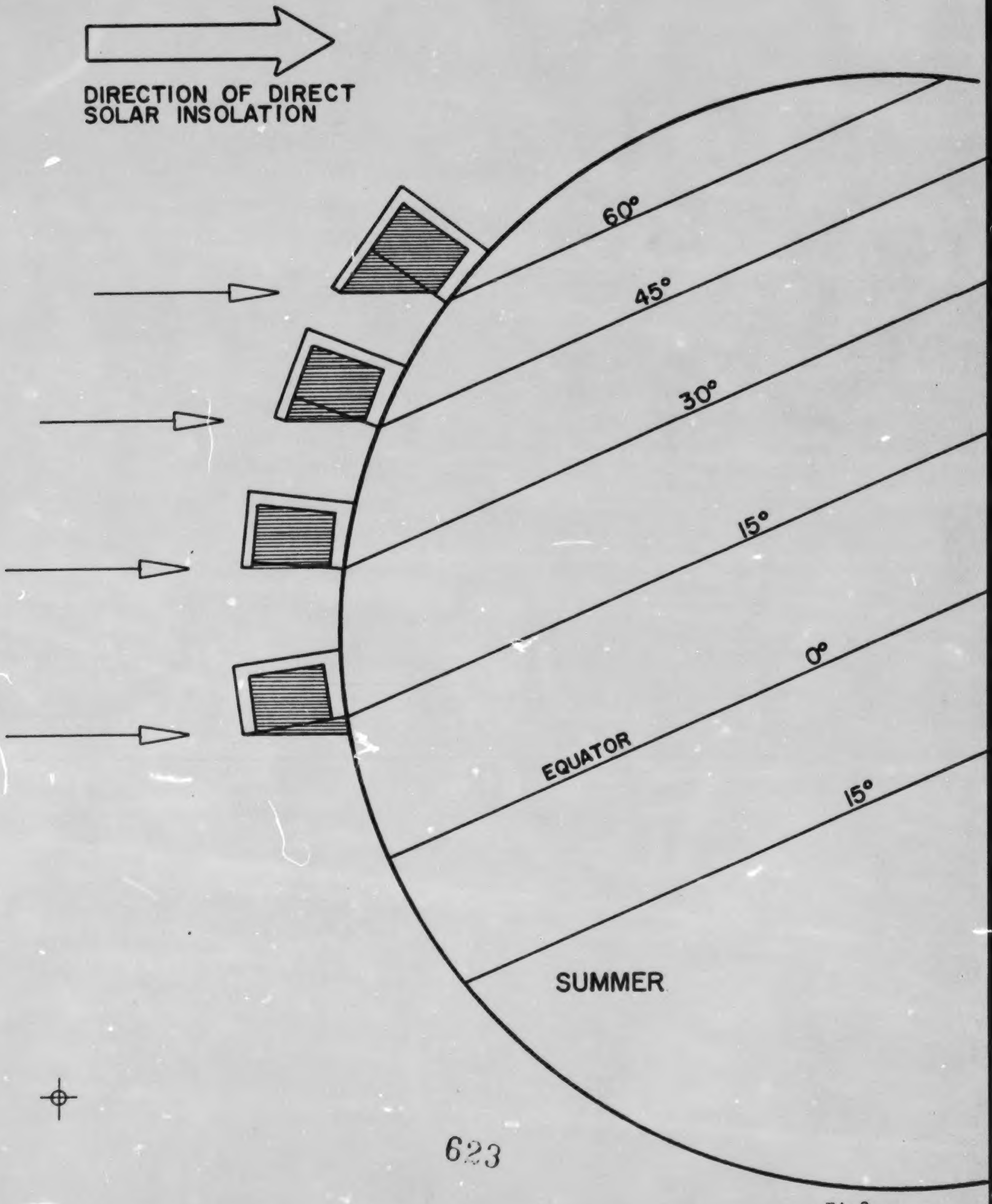
Overhead

Transparency

Masters


60°
45°
30°
15°
EQUATOR
0°
15°
DIRECTION OF DIRECT SOLAR INSOLATION
WINTER

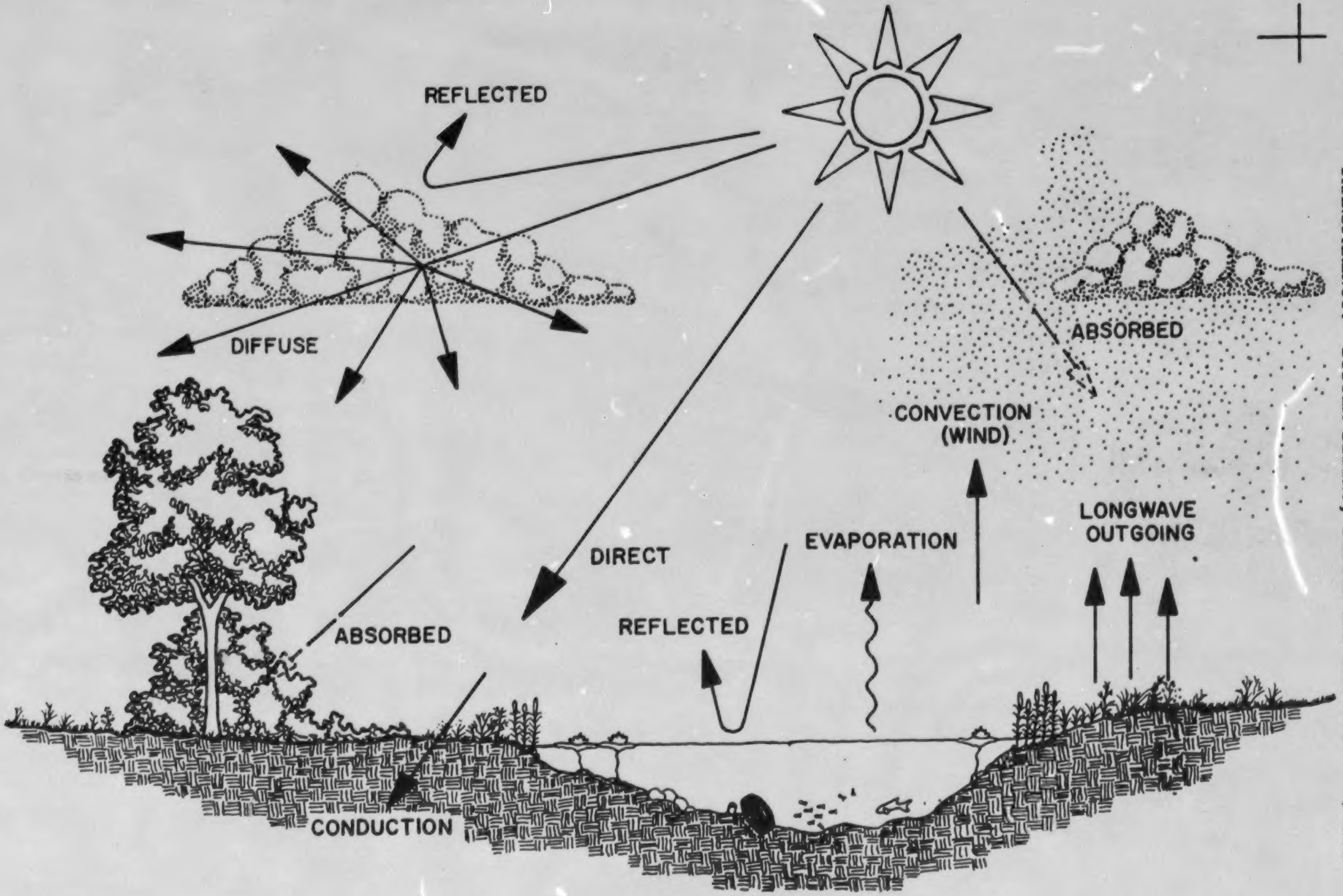
SOUTHERN HEMISPHERE SUMMER DURING NORTHERN HEMISPHERE WINTER


DIRECTION OF DIRECT SOLAR INSOLATION
60°
45°
30°
15°
0°
EQUATOR
15°
SUMMER

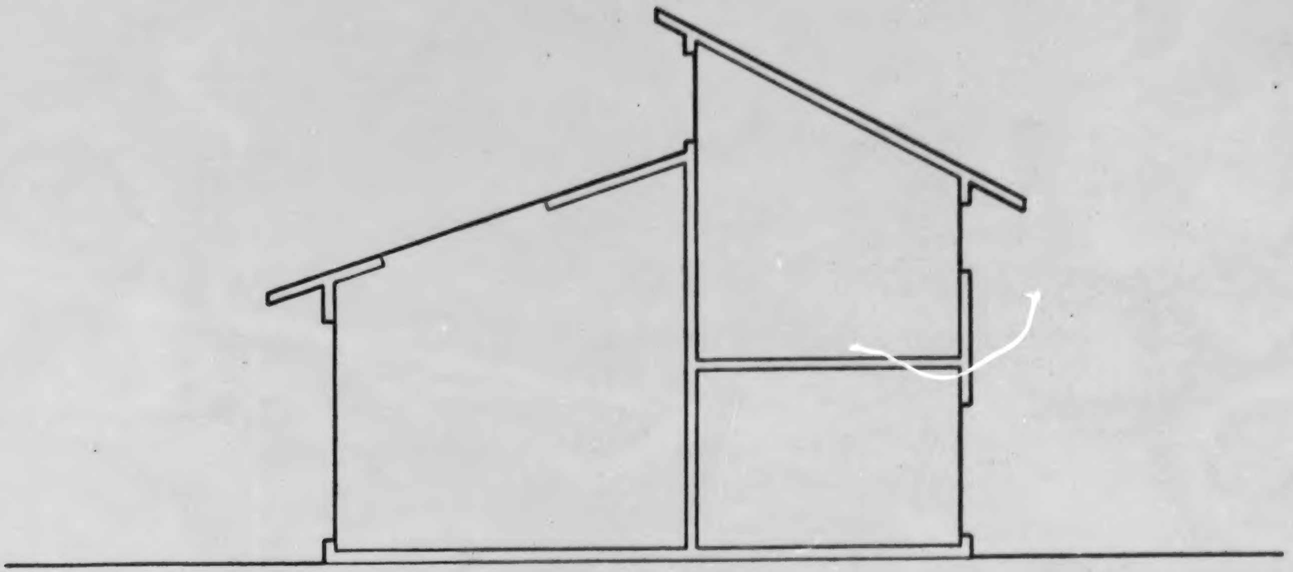
623

SOUTHERN HEMISPHERE WINTER

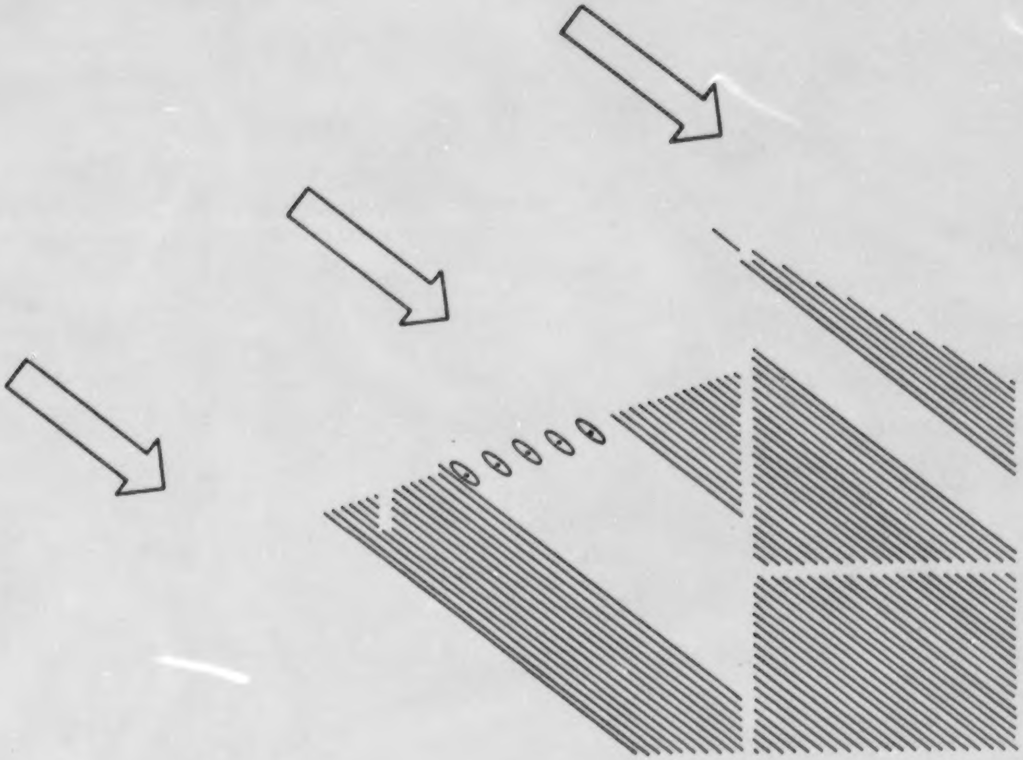
NORTHERN HEMISPHERE SUMMER


REFLECTED
DIFFUSE
DIRECT
ABSORBED
ABSORBED
CONVECTION (WIND)
LONGWAVE OUTGOING
EVAPORATION
REFLECTED
CONDUCTION

PASSIVE SOLAR STRUCTURE

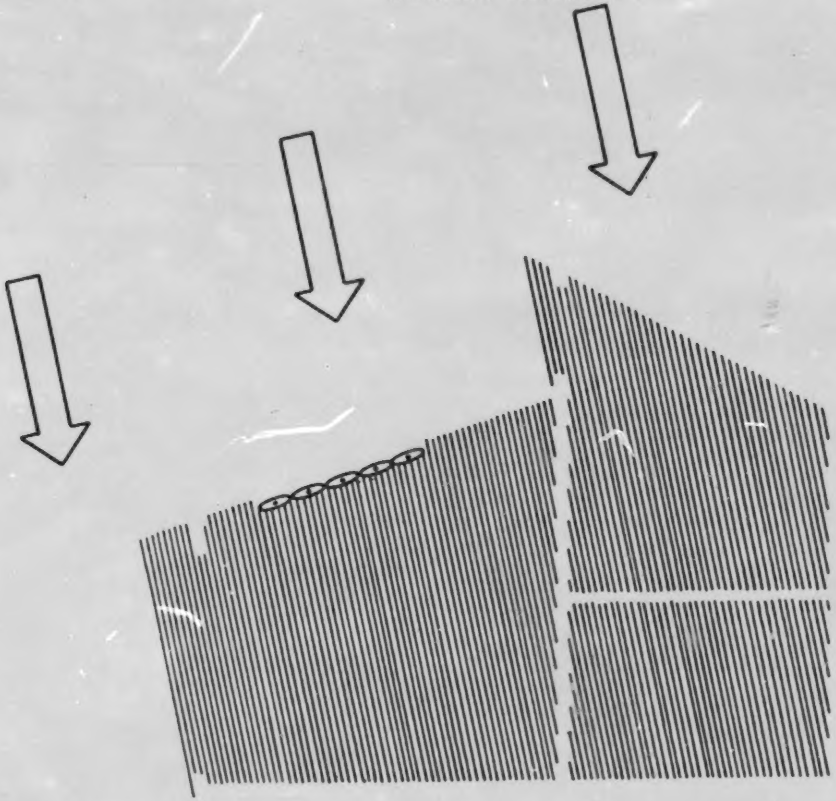


SHADOW PATTERNS



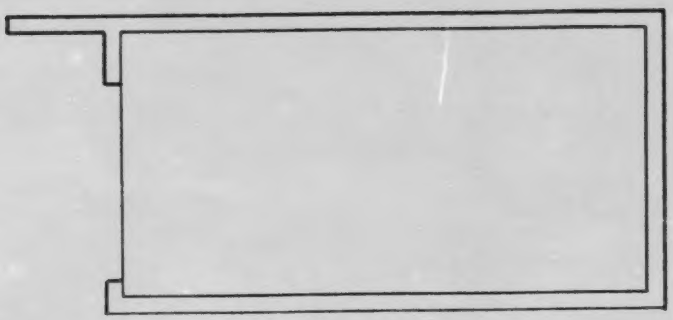
32° NL
JANUARY 21
SOLAR NOON 38°

SHADING PATTERNS

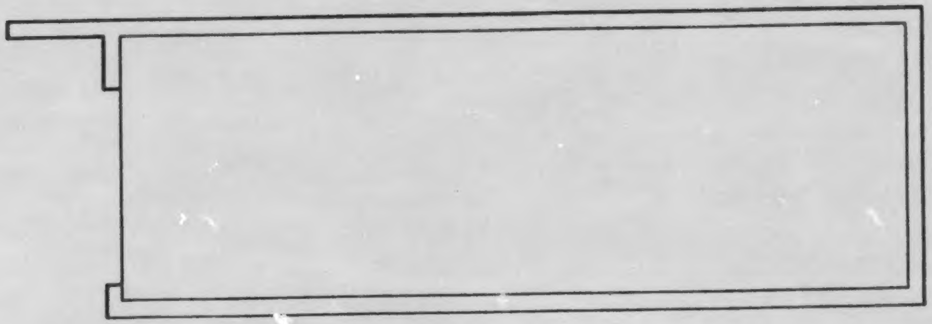


32° NL
JULY 21
SOLAR NOON 78.6°

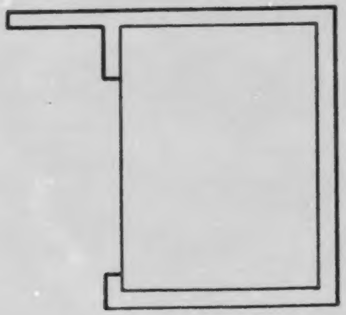
CROSS-SECTION OF INTERIOR SPACE WITH OVERHANG -- MEDIUM DEPTH



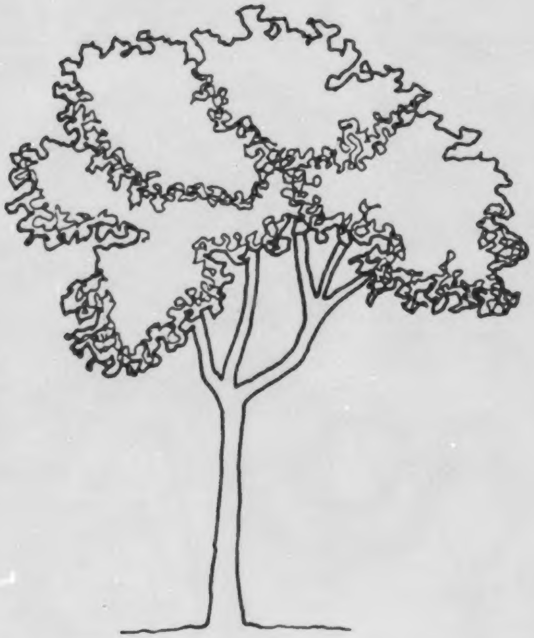
DEEP-SET INTERIOR SPACE
WITH OVERHANG



SHALLOW-SET INTERIOR SPACE
WITH OVERHANG

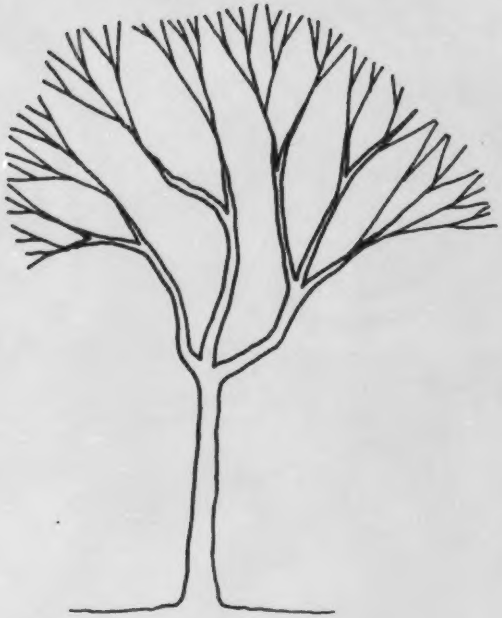


SUMMER DECIDUOUS TREE



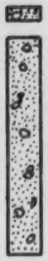
PA-5, 6, 7-A

WINTER DECIDUOUS TREE



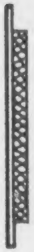
PA-5, 6, 7-B

TROMBE WALL



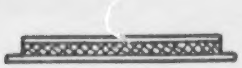
WATER WALL

CLOSED NIGHTTIME EXTERIOR INSULATION



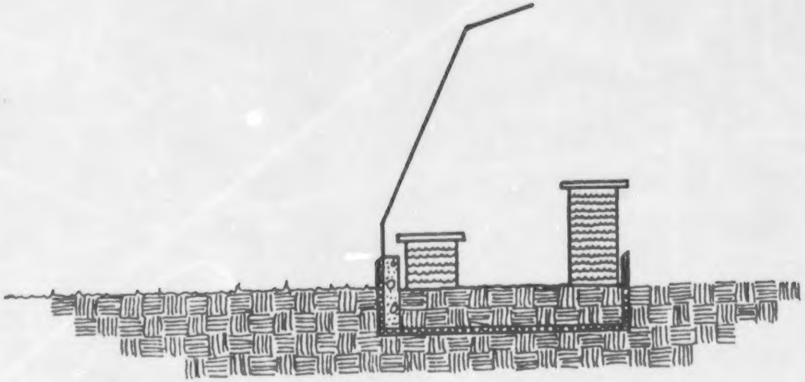
PA-5, 6, 7-E

OPEN INSULATING DEVICE

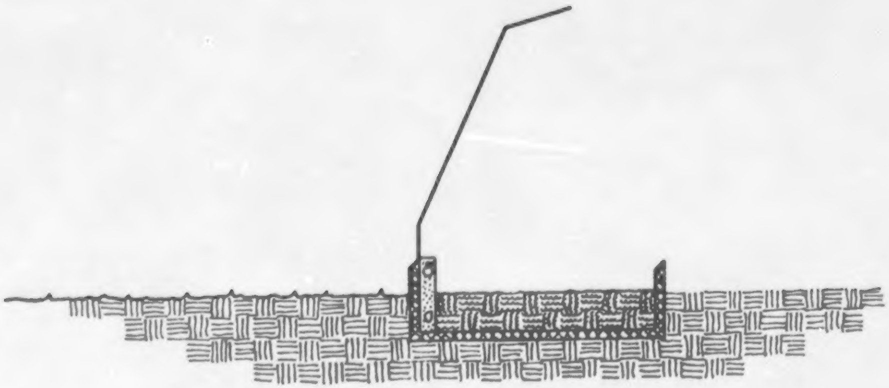


PA-5, 6, 7-F

SUNSPACE WITH WATER STORAGE

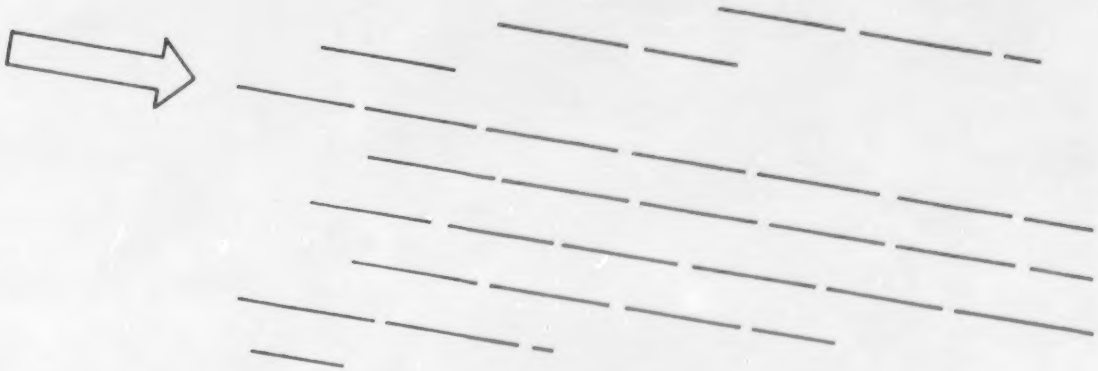


DIRECT GAIN SUNSPACE



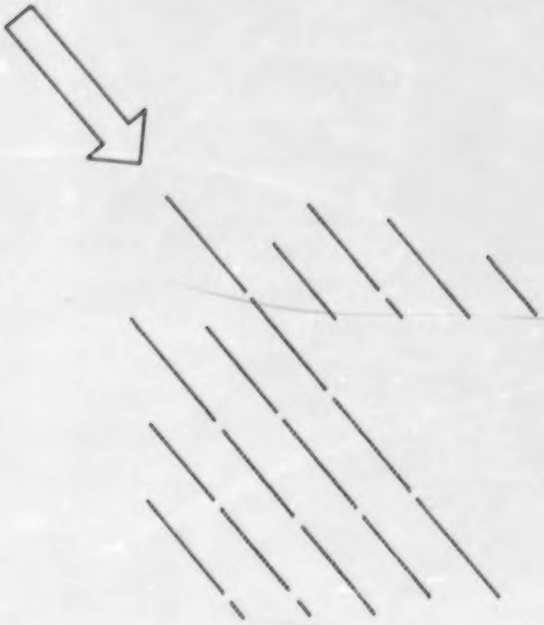
INSOLATION DIRECTION

60° NL
JANUARY 21
SOLAR NOON 10°



PA-5, 6, 7-I

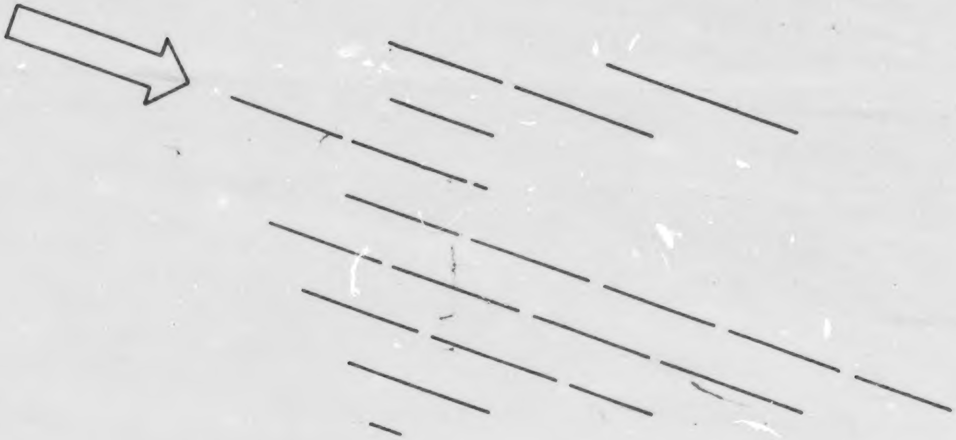
INSOLATION DIRECTION



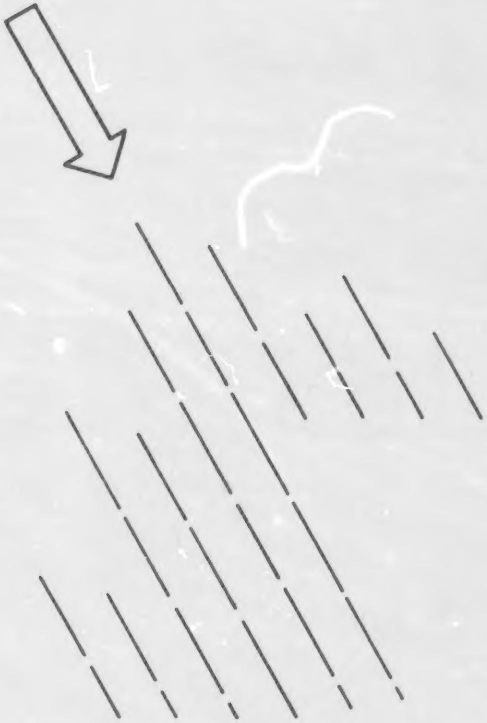
60° NL
JULY 21
SOLAR NOON 50.6°

INSOLATION DIRECTION

50° NL
JANUARY 21
SOLAR NOON 20°



INSOLATION DIRECTION

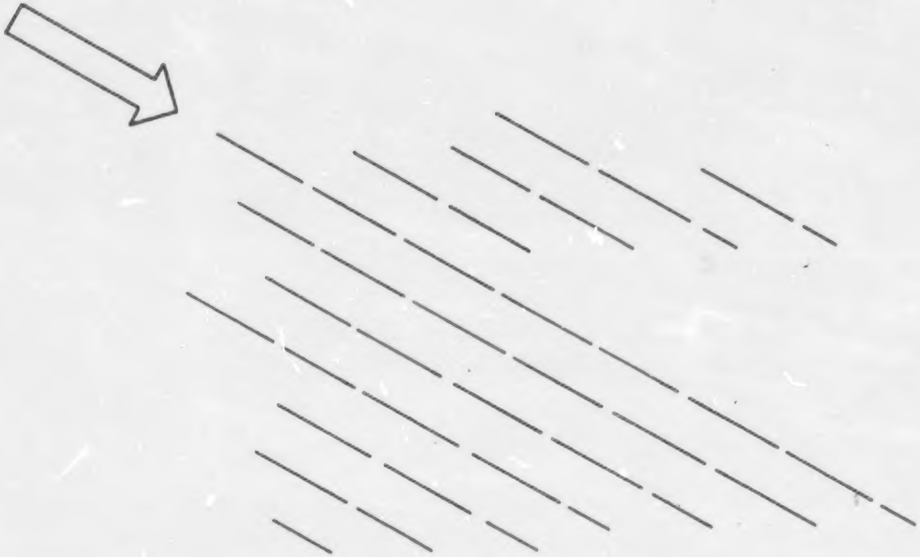


50° NL
JULY 21
SOLAR NOON 60.6°

PA-5, 6, 7-L

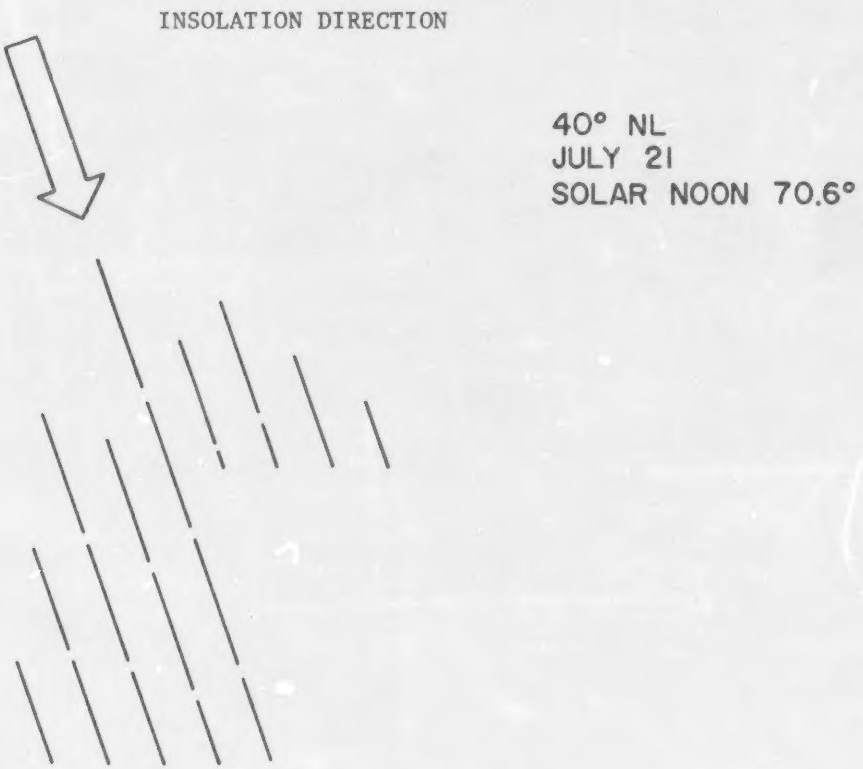
INSOLATION DIRECTION

40° NL
JANUARY 21
SOLAR NOON 30°



TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT V-321

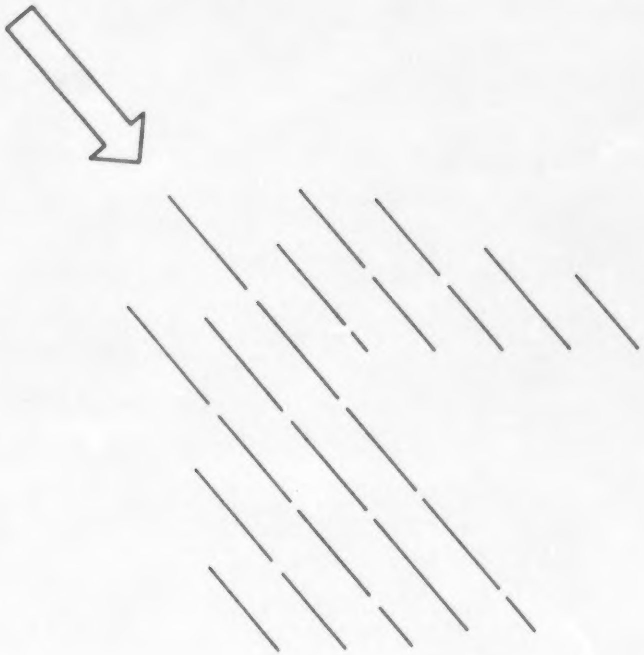
PA-5, 6, 7-M


INSOLATION DIRECTION
40° NL
JULY 21
SOLAR NOON 70.6°

TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT V-323

PA-5, 6, 7-N

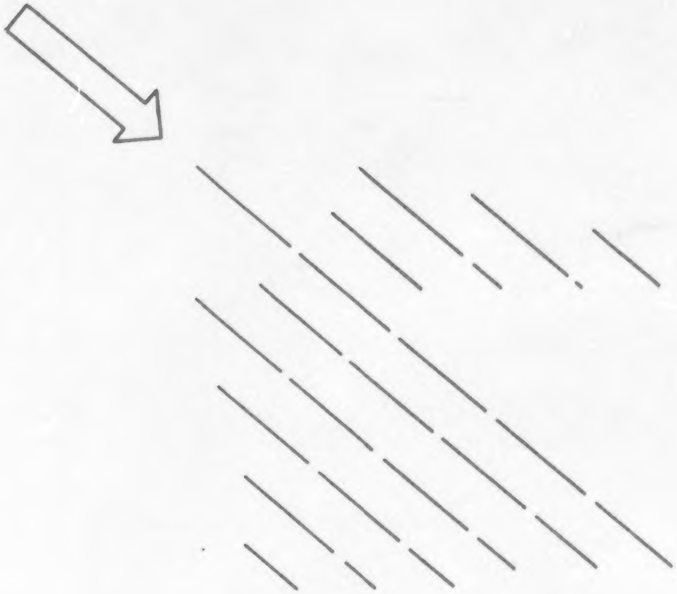
INSOLATION DIRECTION



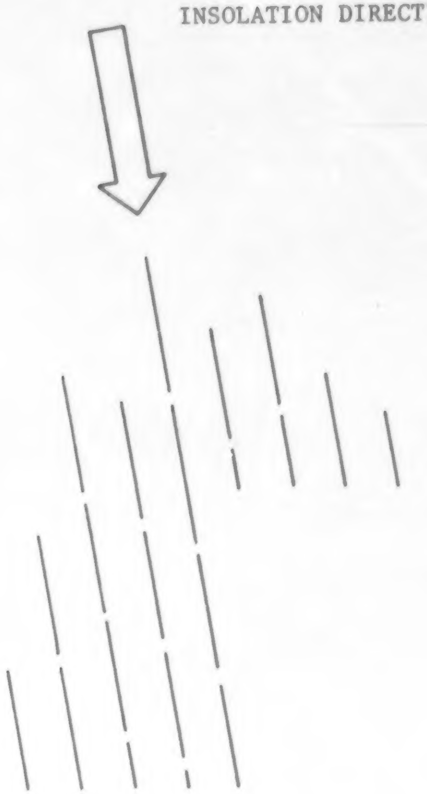
40° NL
SPRING/FALL EQUINOX
SOLAR NOON 50°

INSOLATION DIRECTION

30° NL
JANUARY 21
SOLAR NOON 40°



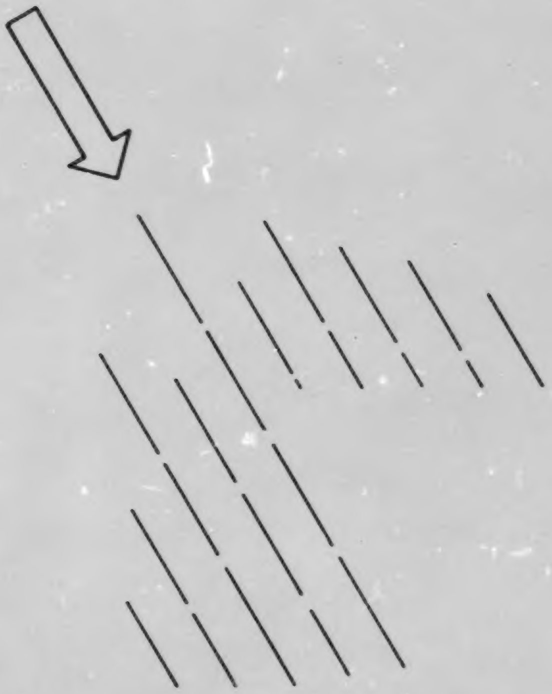
PA-5, 6, 7-P



INSOLATION DIRECTION
30° NL
JULY 21
SOLAR NOON 80,6°

TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT

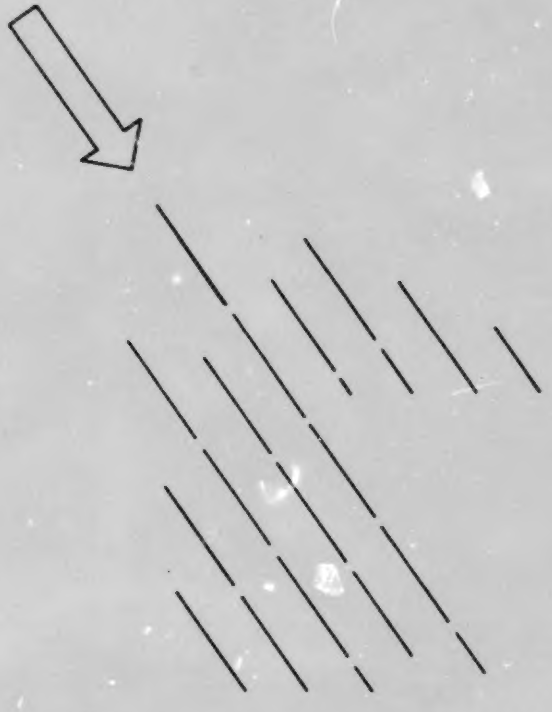
TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT V-331


INSOLATION DIRECTION

30° NL
SPRING/FALL EQUINOX
SOLAR NOON 60°

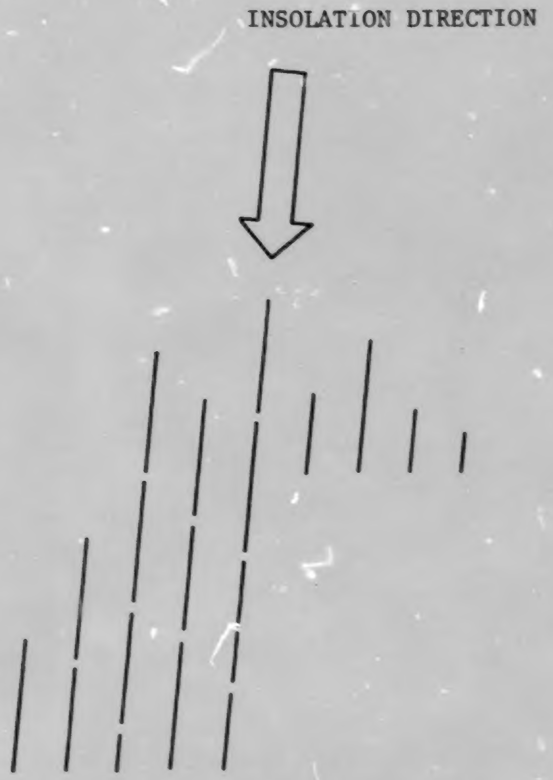
PA-5, 6, 7-R

INSOLATION DIRECTION



15° NL
JANUARY 21
SOLAR NOON 55°

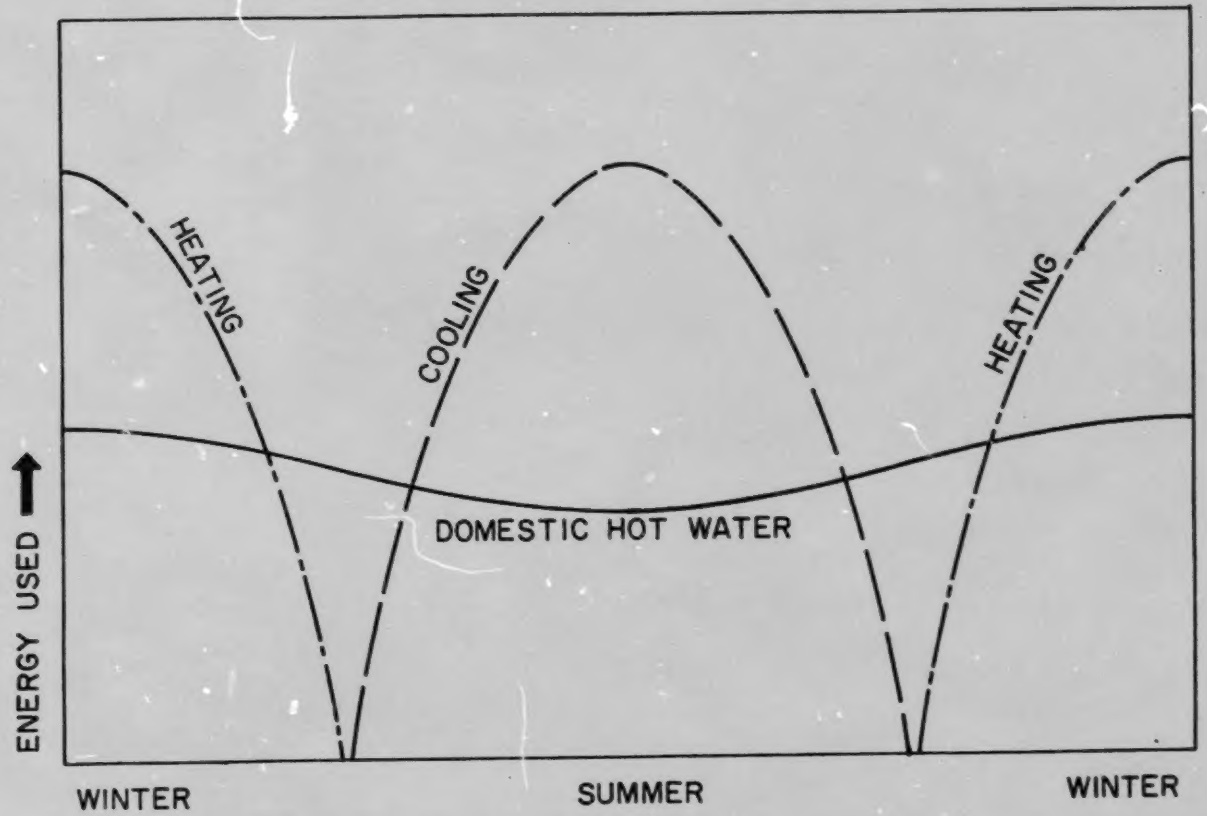
PA-5, 6, 7-S


INSOLATION DIRECTION

15° NL
JULY 21
SOLAR NOON 95.6°

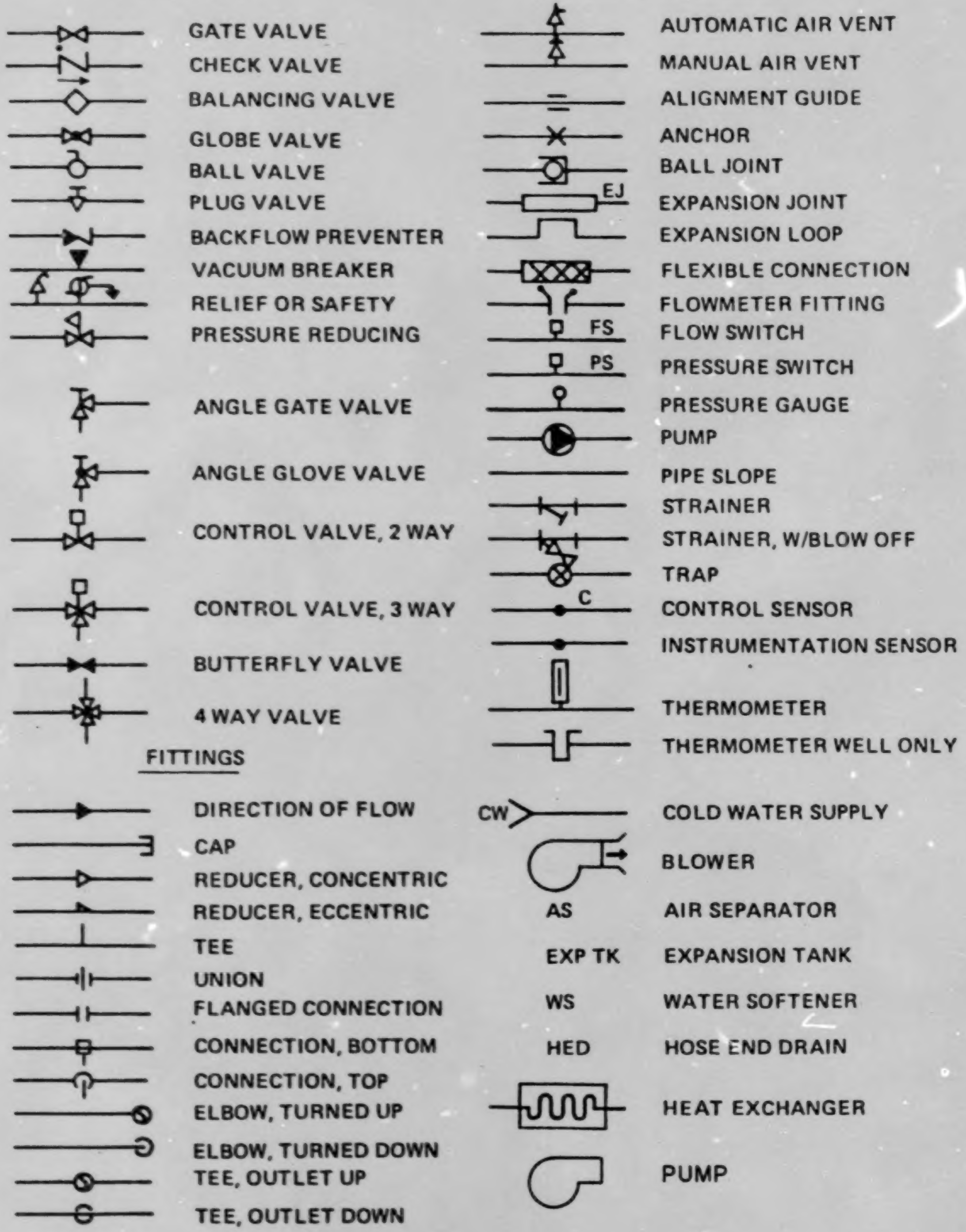
PA-5, 6, 7-T

DOMESTIC ENERGY USE PATTERNS



TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT

Legend For Solar System Schematics



VALVES

- GATE VALVE
- CHECK VALVE
- BALANCING VALVE
- GLOBE VALVE
- BALL VALVE
- PLUG VALVE
- BACKFLOW PREVENTER
- VACUUM BREAKER
- RELIEF OR SAFETY
- PRESSURE REDUCING
- ANGLE GATE VALVE
- ANGLE GLOVE VALVE
- CONTROL VALVE, 2 WAY
- CONTROL VALVE, 3 WAY
- BUTTERFLY VALVE
- 4 WAY VALVE

FITTINGS

- DIRECTION OF FLOW
- CAP
- REDUCER, CONCENTRIC
- REDUCER, ECCENTRIC
- TEE
- UNION
- FLANGED CONNECTION
- CONNECTION, BOTTOM
- CONNECTION, TOP
- ELBOW, TURNED UP
- ELBOW, TURNED DOWN
- TEE, OUTLET UP
- TEE, OUTLET DOWN

PIPING SPECIALITIES

- AUTOMATIC AIR VENT
- MANUAL AIR VENT
- ALIGNMENT GUIDE
- ANCHOR
- BALL JOINT
- EXPANSION JOINT
- EXPANSION LOOP
- FLEXIBLE CONNECTION
- FLOWMETER FITTING
- FLOW SWITCH
- PRESSURE SWITCH
- PRESSURE GAUGE
- PUMP
- PIPE SLOPE
- STRAINER
- STRAINER, W/BLOW OFF
- TRAP
- CONTROL SENSOR
- INSTRUMENTATION SENSOR
- THERMOMETER
- THERMOMETER WELL ONLY
- COLD WATER SUPPLY
- BLOWER

AS	AIR SEPARATOR
EXP TK	EXPANSION TANK
WS	WATER SOFTENER
HED	HOSE END DRAIN

- HEAT EXCHANGER
- PUMP

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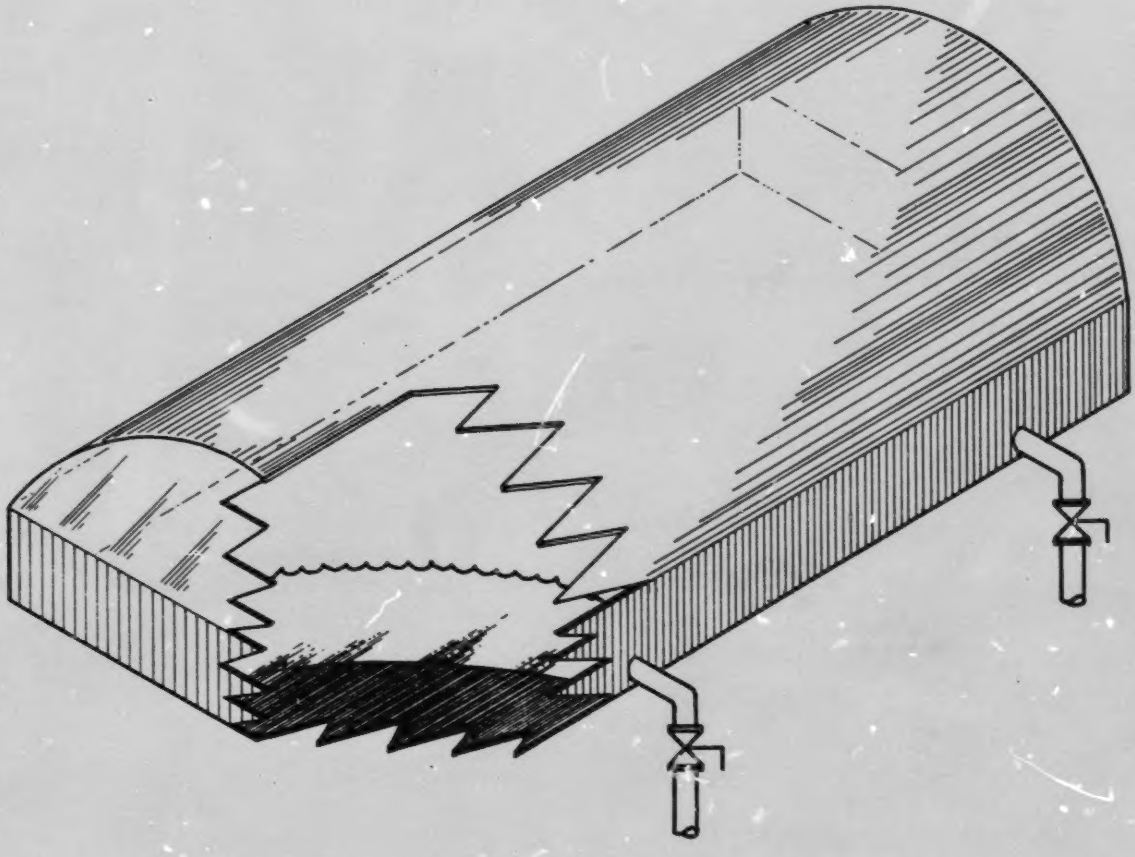
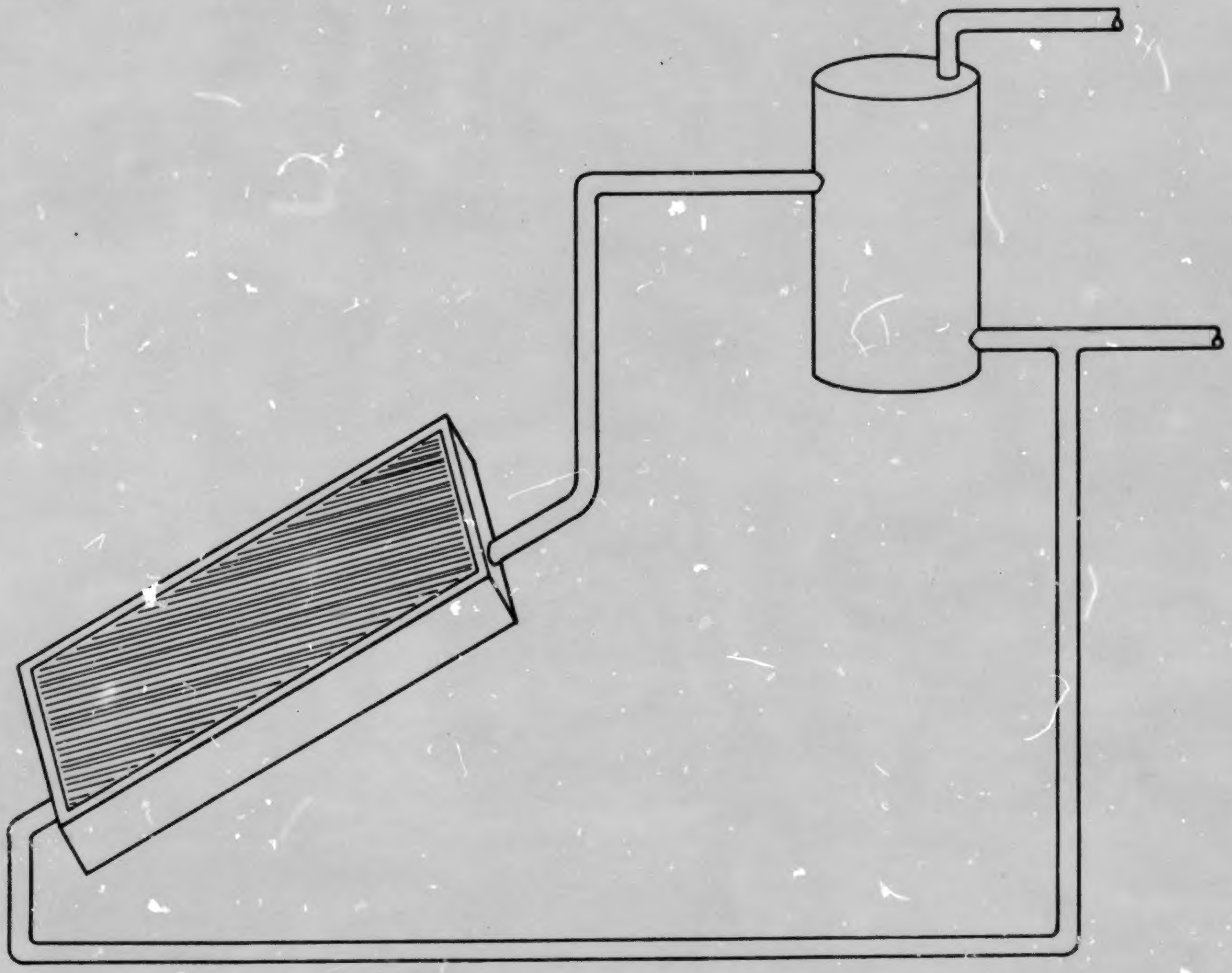
SOLAR BATCH WATER HEATER

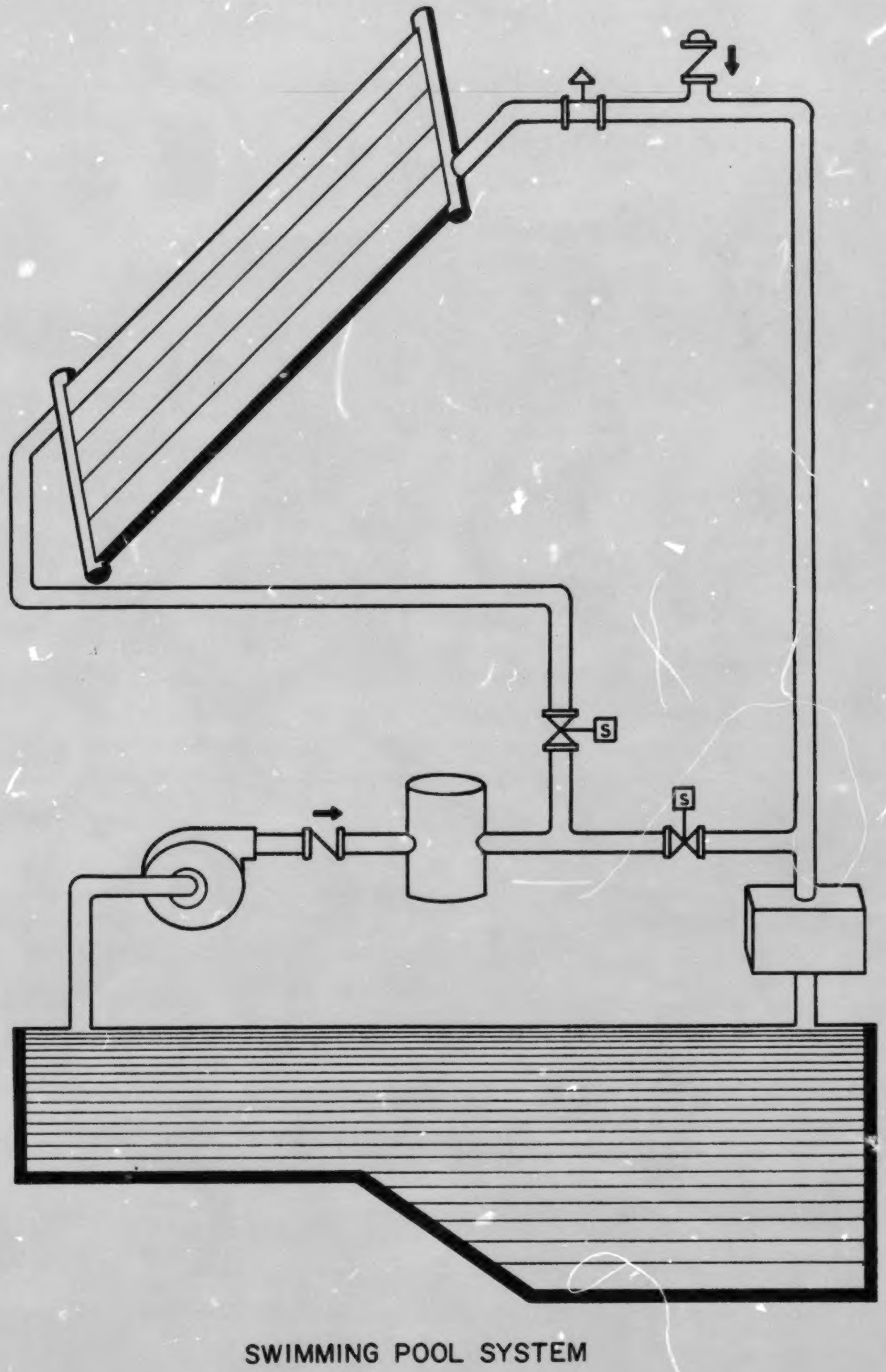


TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT V-343



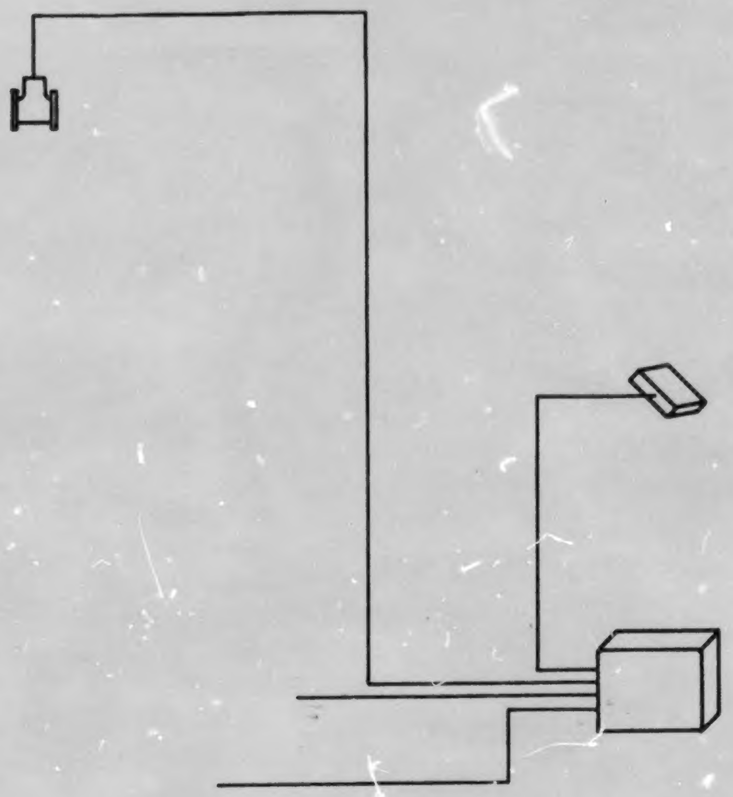
THERMOSIPHON

SM-3-A



SWIMMING POOL SYSTEM

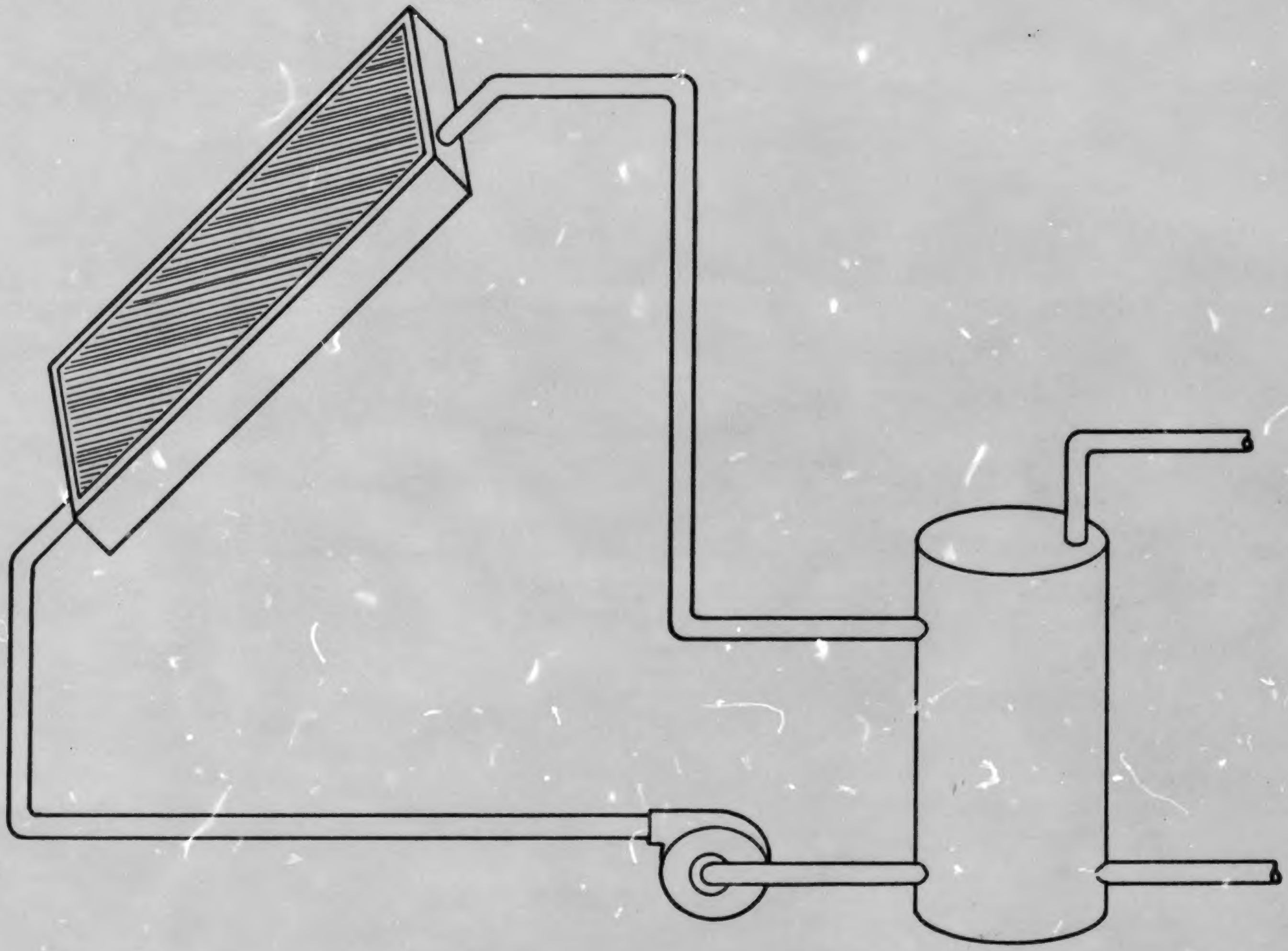
SOLAR POOL HEATING CONTROLS



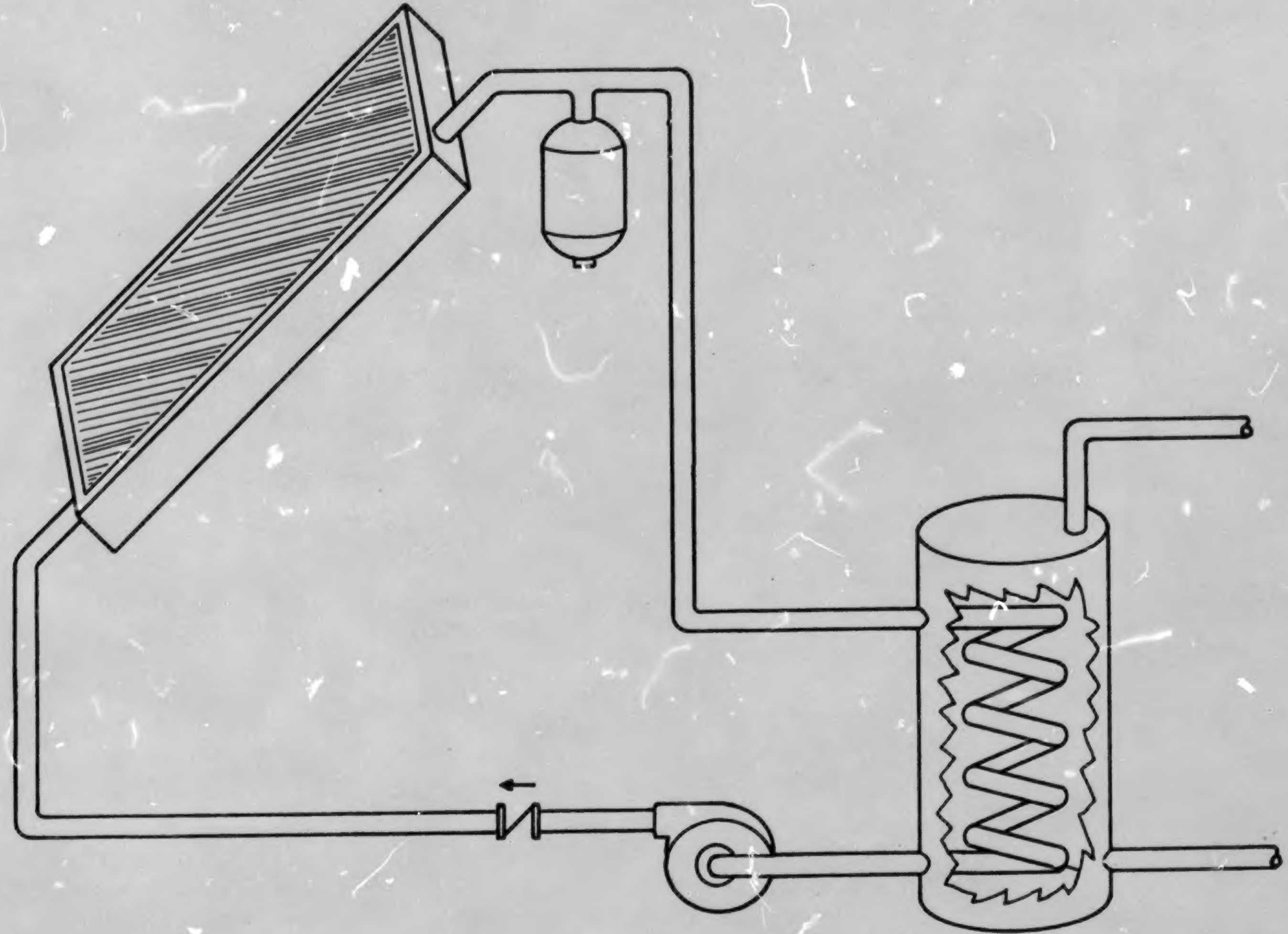
TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT

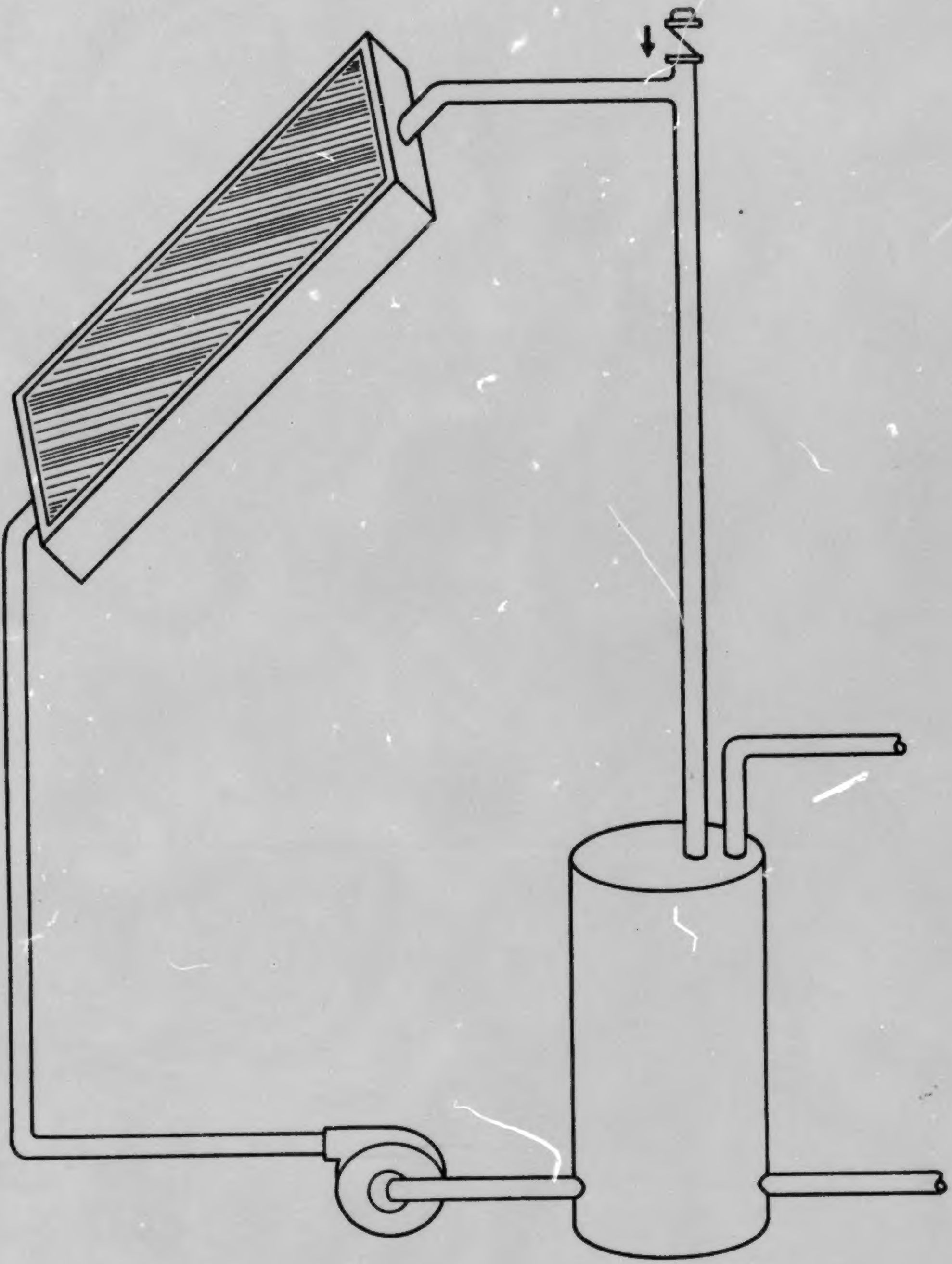
SM-4-A

CLOSED-LOOP SOLAR DHW



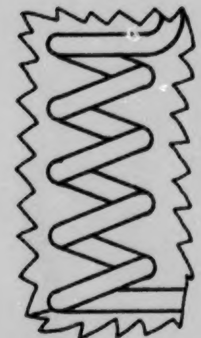
CLOSED-LOOP SOLAR DHW WITH COMPONENTS

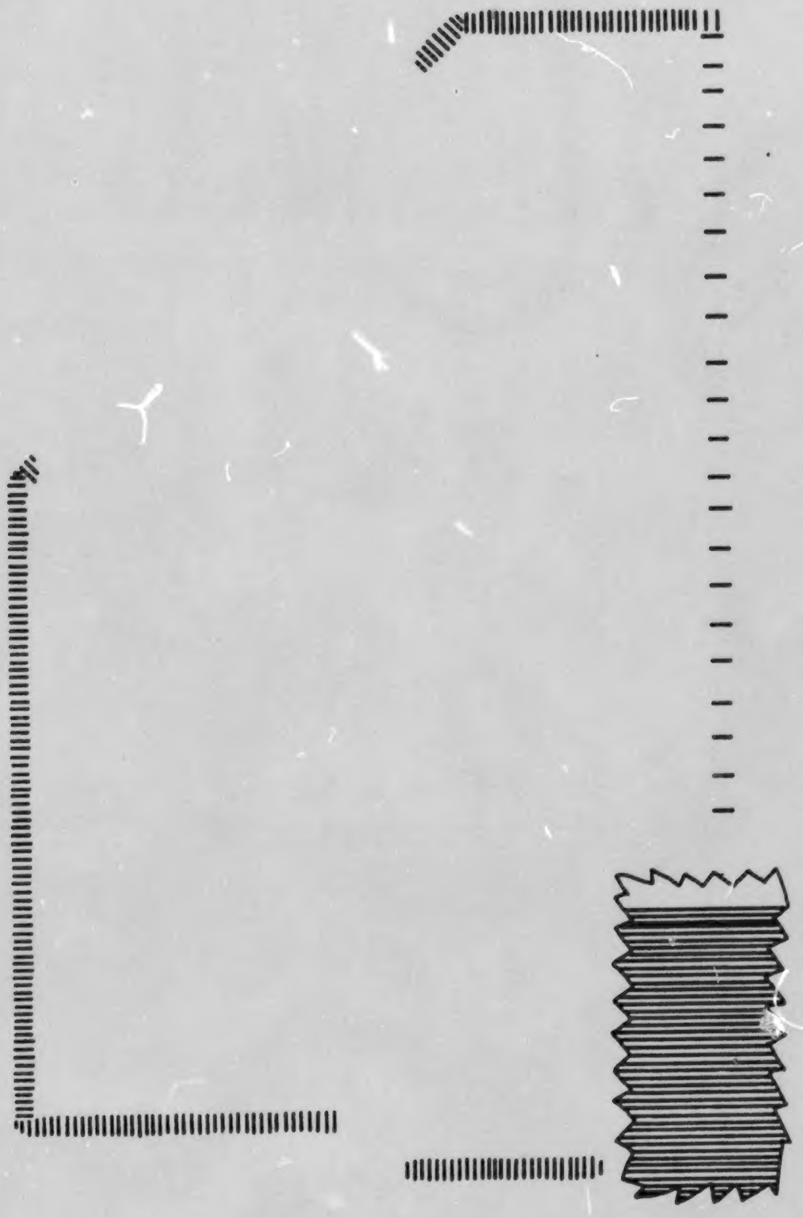




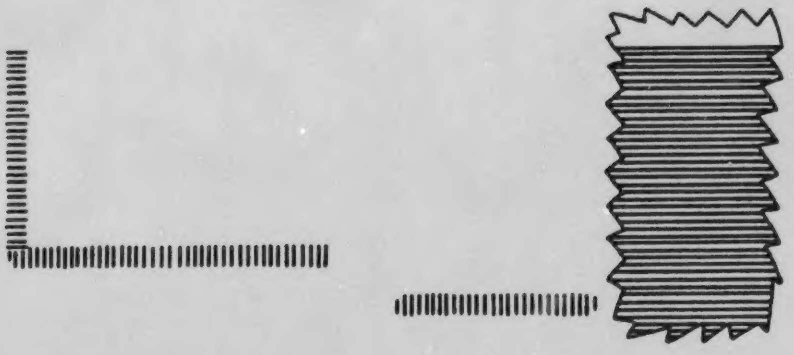
DRAIN BACK OPEN SYSTEM

CUT-AWAY OF TANK WITH EXCHANGER

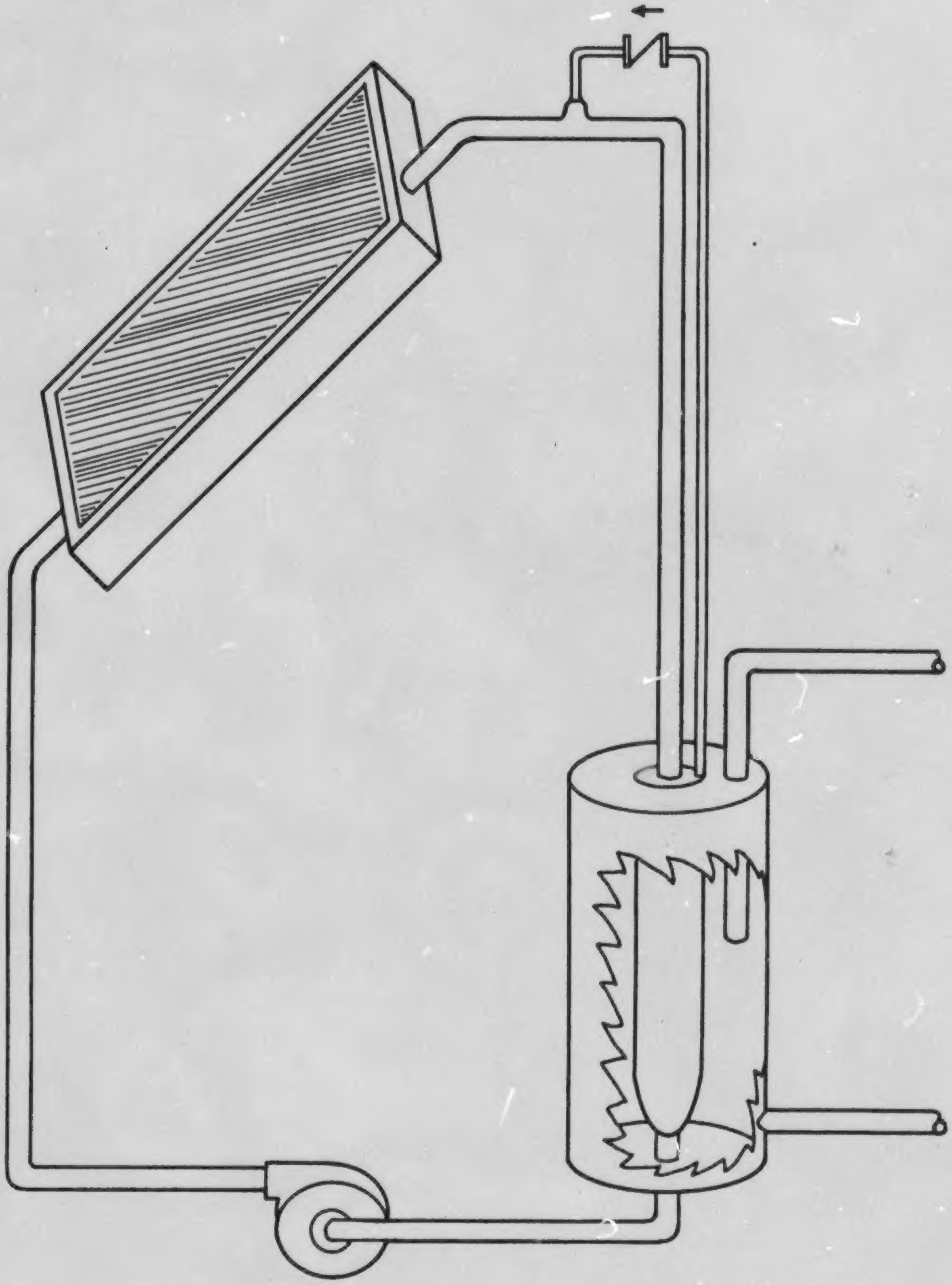




PUMP RUNNING

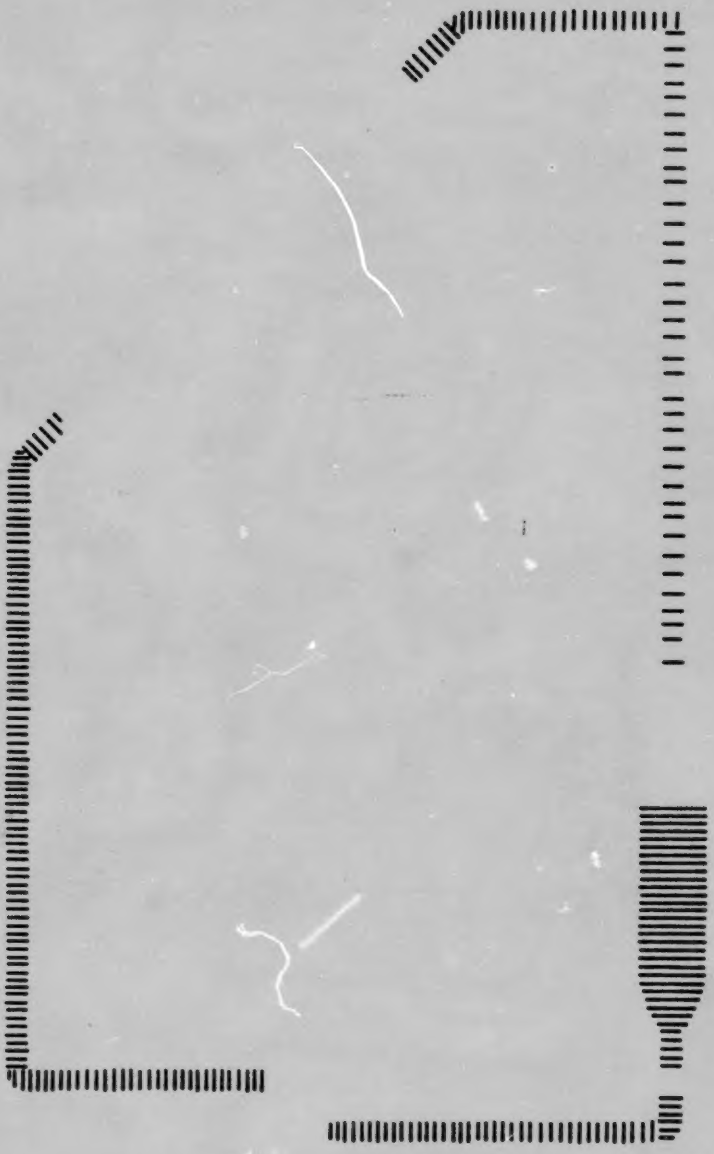


PUMP NOT RUNNING



DRAIN BACK CLOSED SYSTEM

697



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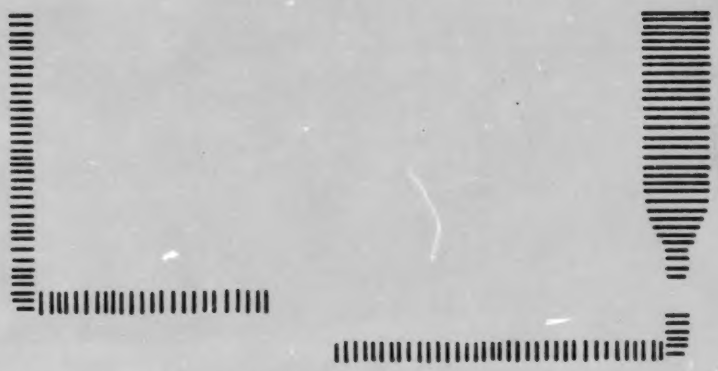

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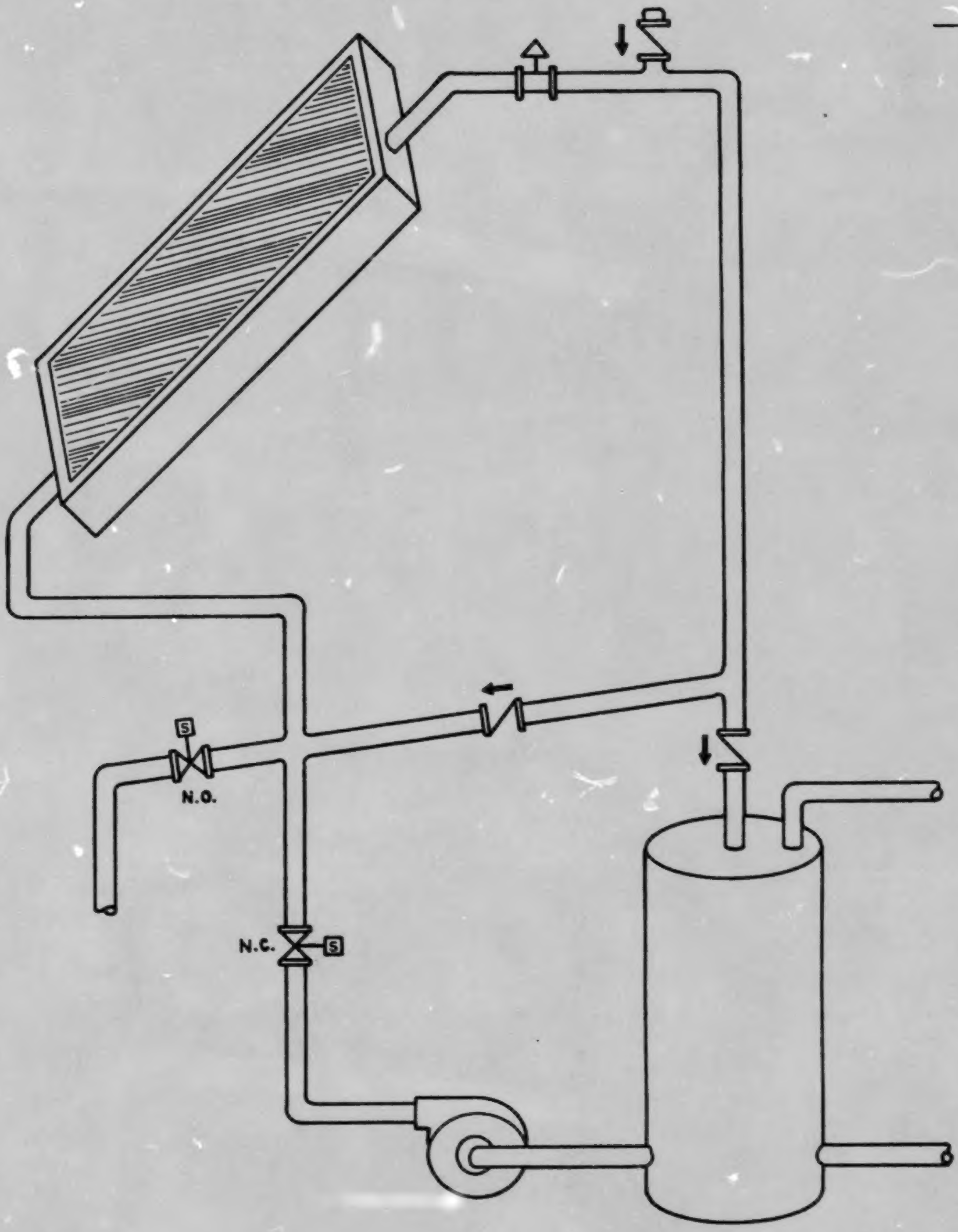
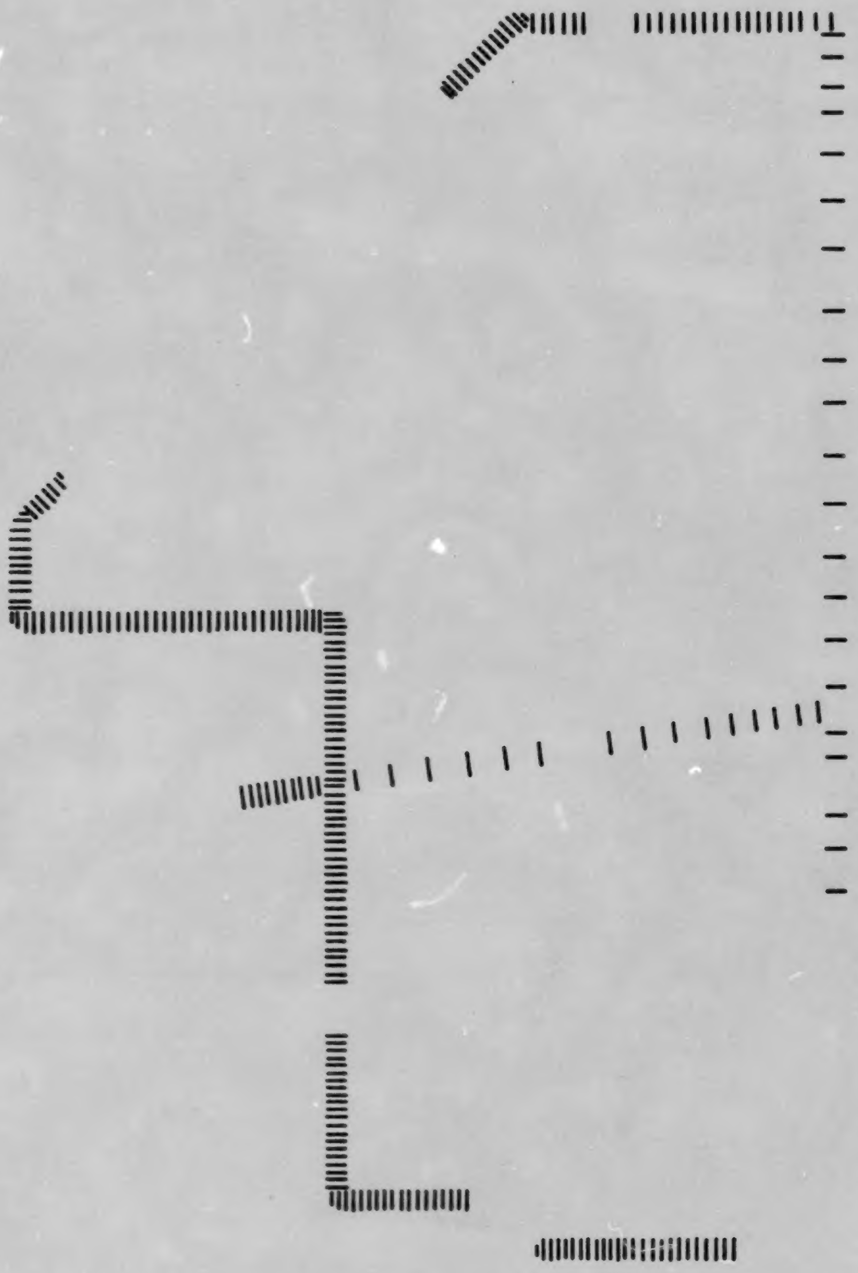


DRAIN DOWN



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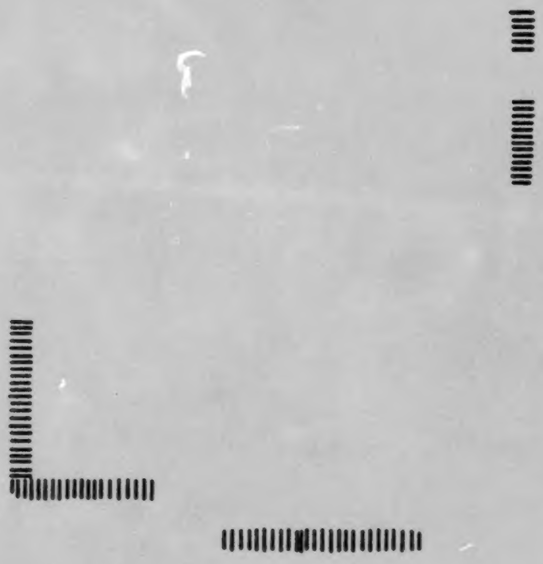
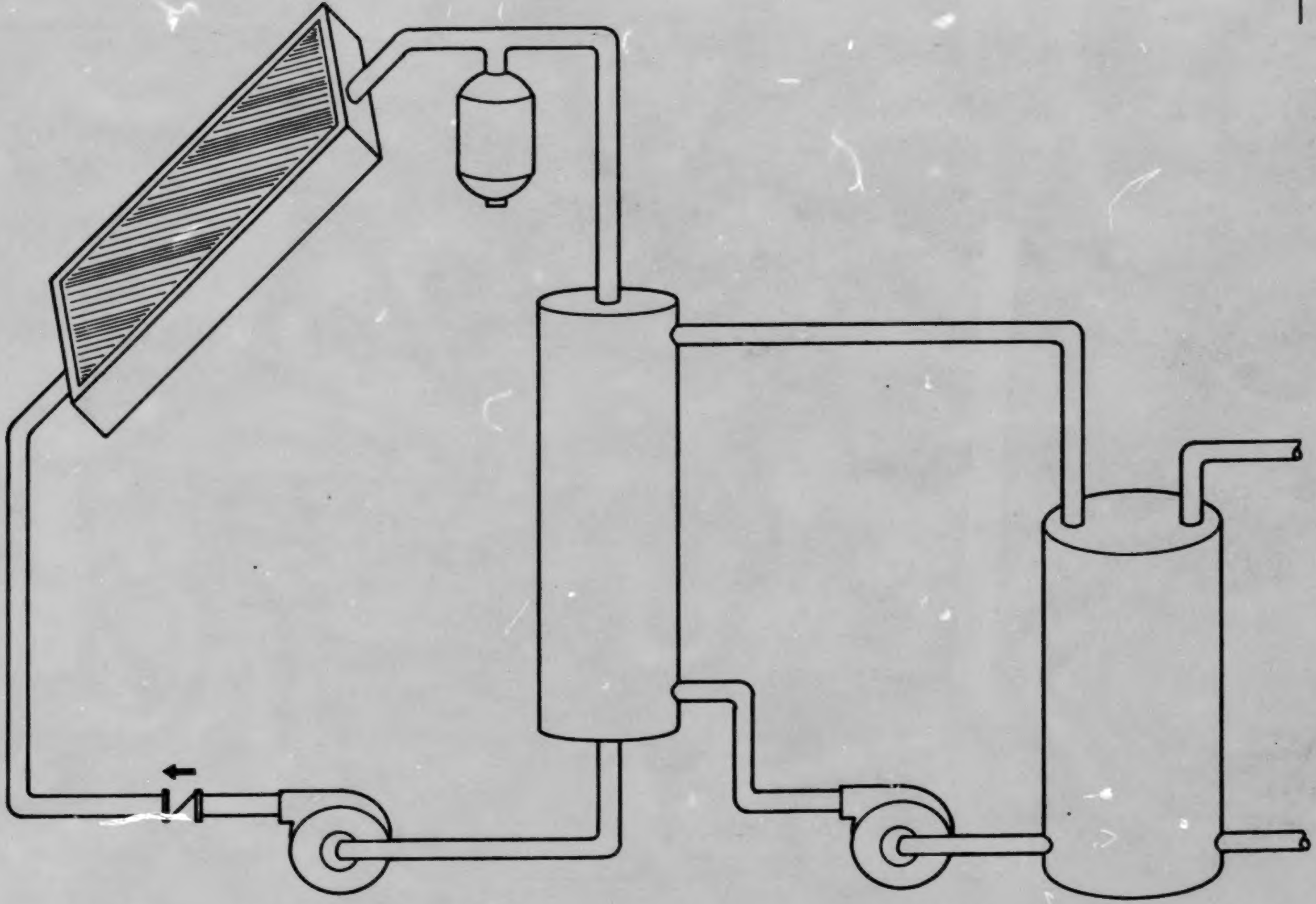


PUMP NOT RUNNING



SYSTEM WITH SEPARATE HEAT EXCHANGER

COMPONENTS OF EXTERNAL HEAT EXCHANGER SOLAR DHW

COLLECTOR
ARRAY

EXPANSION
TANK

SOLAR
HEATED
WATER
OUT

HEAT
EXCHANGER

CHECK
VALVE

SOLAR PUMP

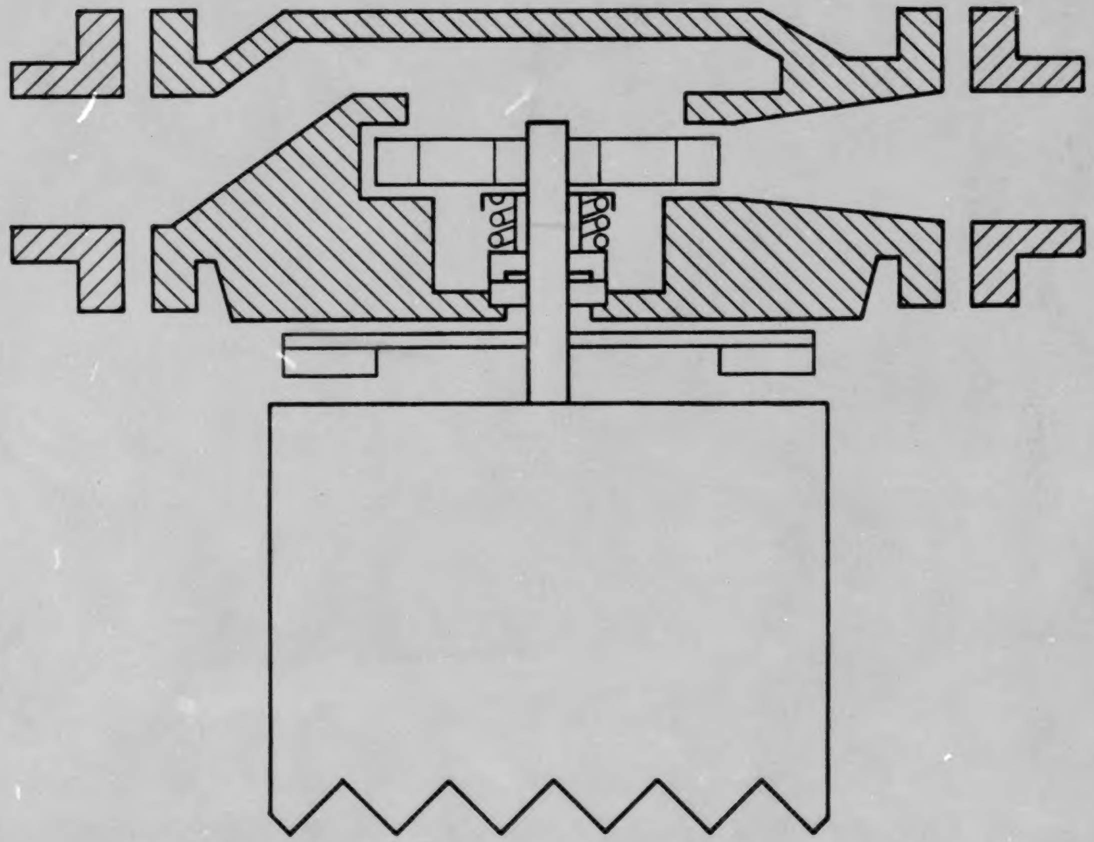
HOT WATER PUMP

CITY
WATER
IN

TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT V-375

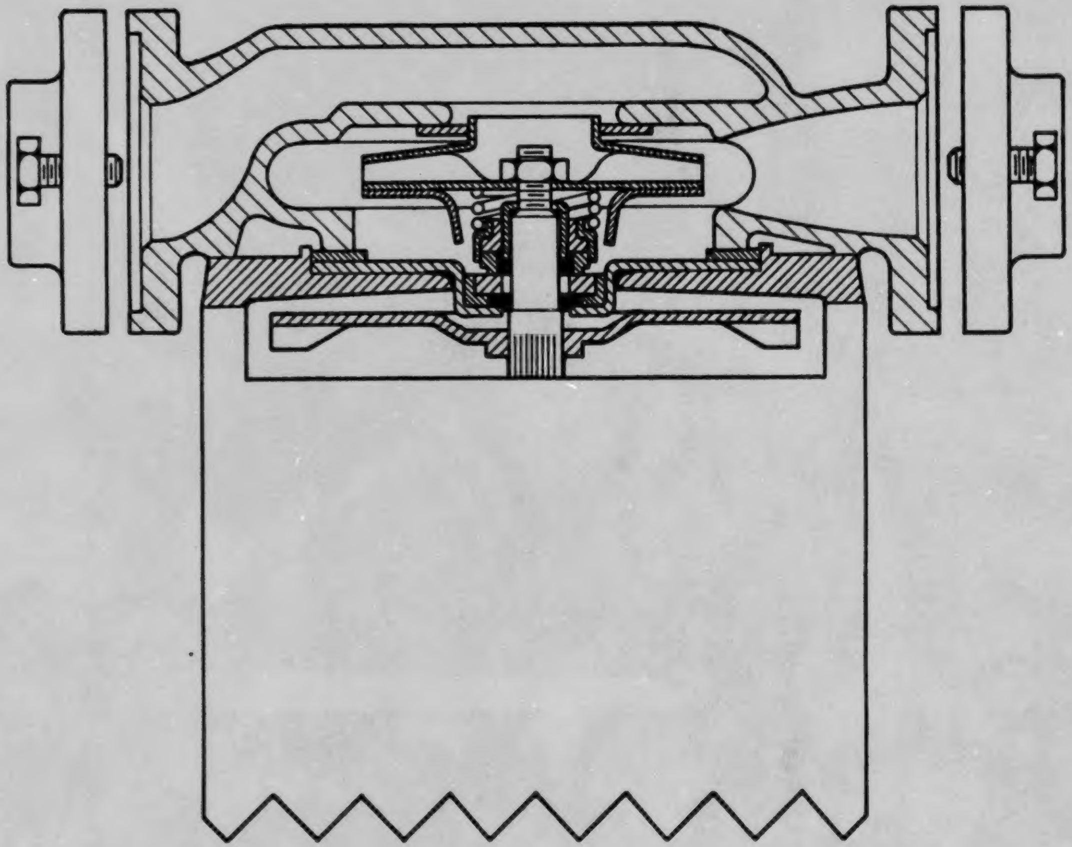
SM-10-A

SOLENOID VALVE



707

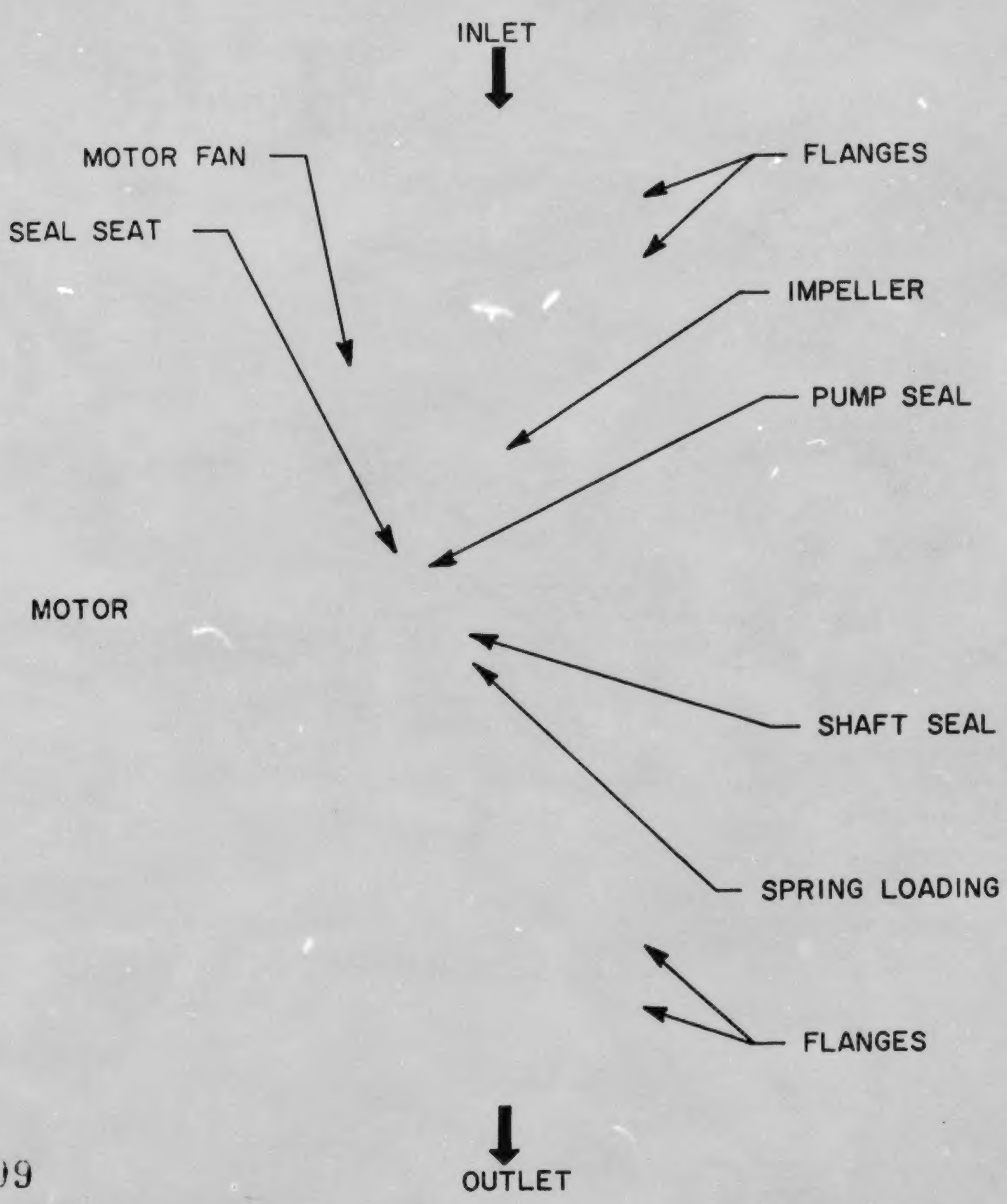
SOLENOID VALVE



COMPONENTS

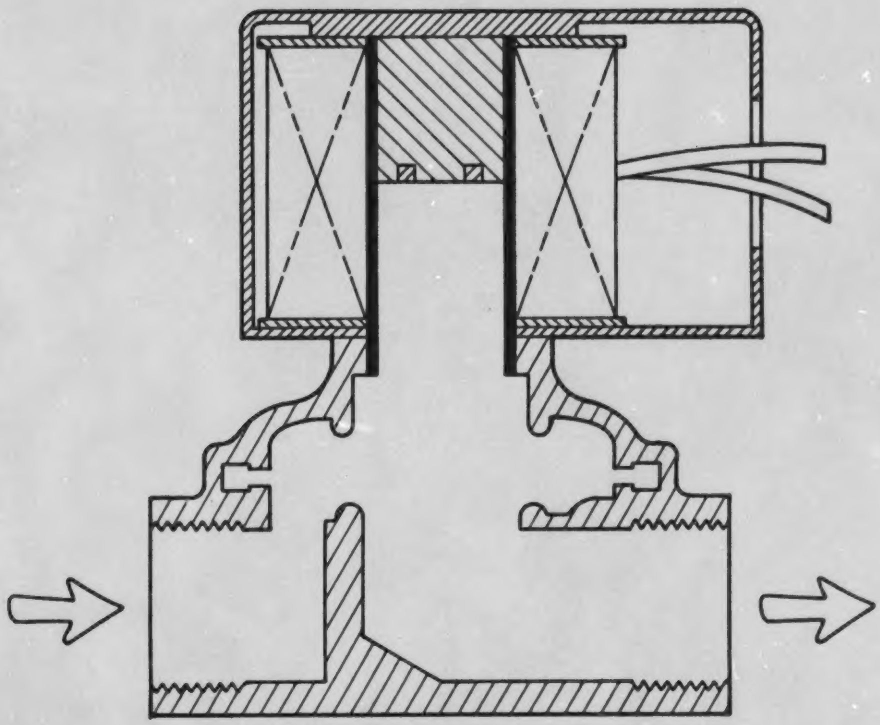
OF

SOLENOID VALVE


INLET
MOTOR FAN
SEAL SEAT
FLANGES
IMPELLER
PUMP SEAL
MOTOR
SHAFT SEAL
SPRING LOADING
FLANGES
OUTLET

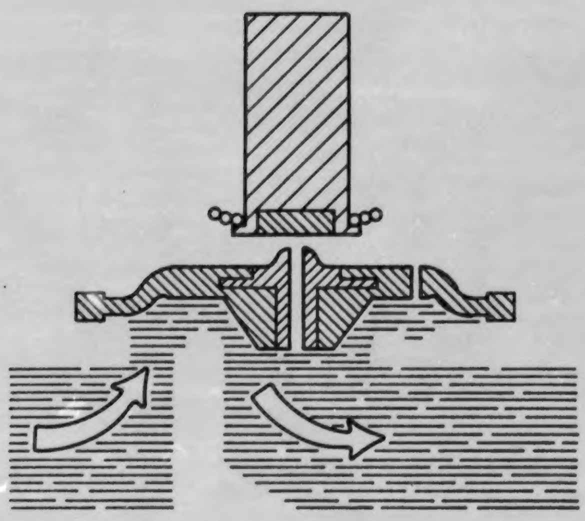
TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT V-381

PC-2, 3-A

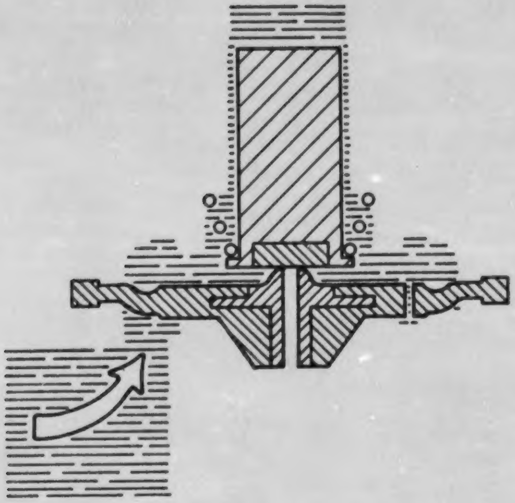


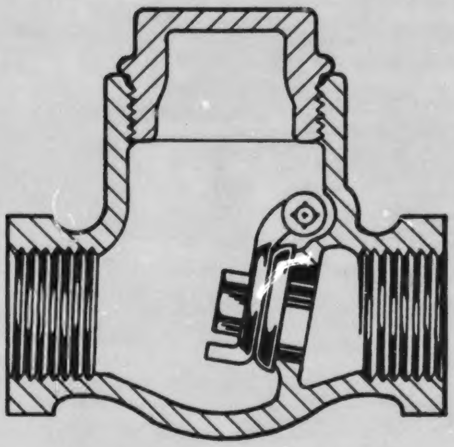
SOLENOID VALVE

OPEN SOLENOID VALVE

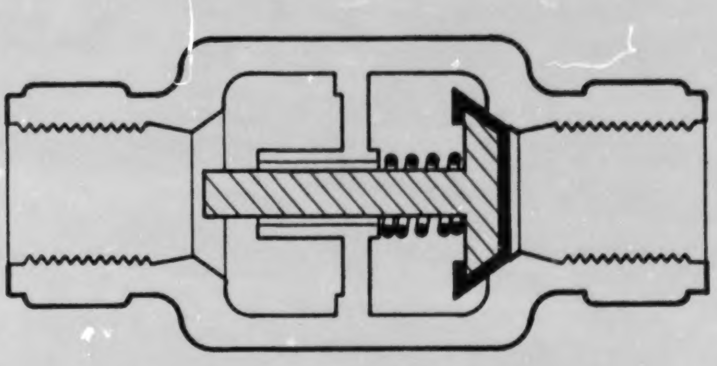


CLOSED SOLENOID VALVE

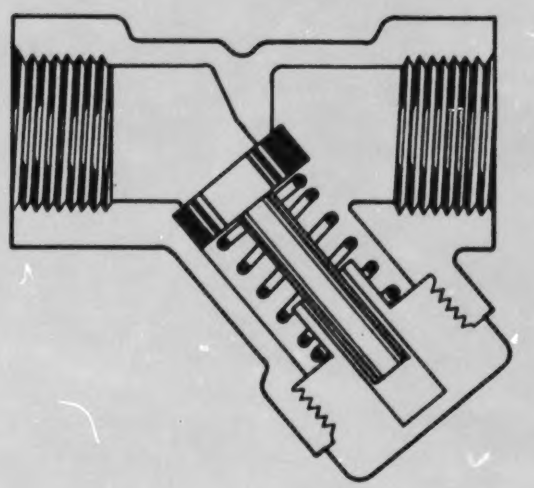




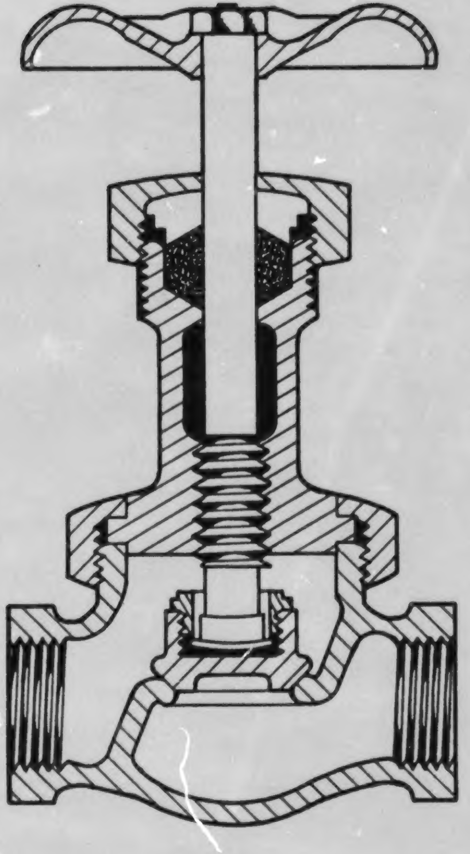
SWING CHECK VALVE



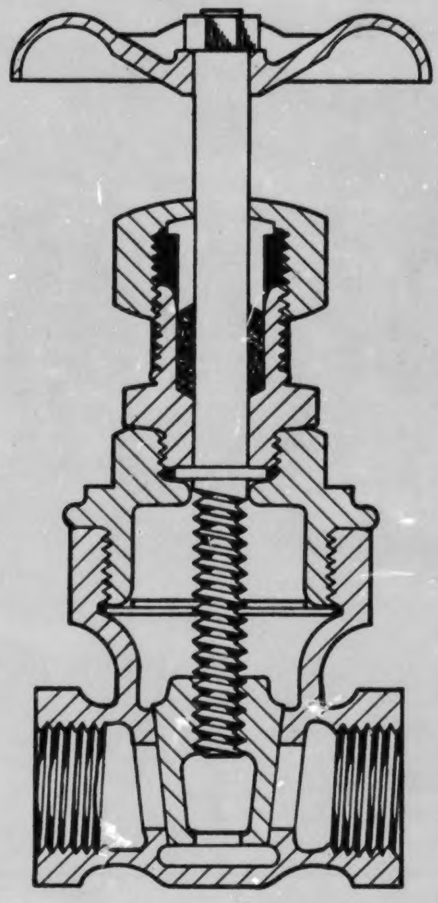
SPRING-LOADED CHECK VALVE



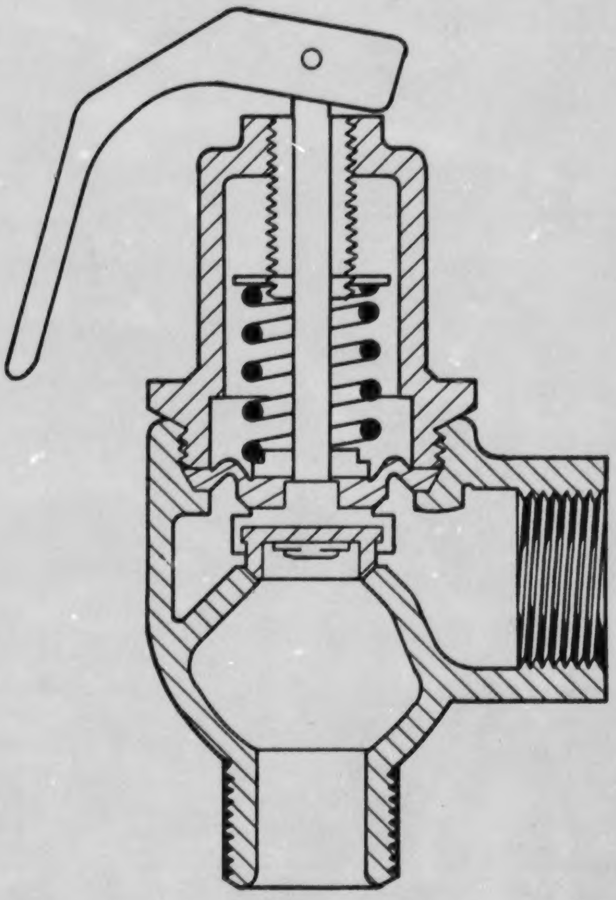
SPRING-LOADED CHECK VALVE



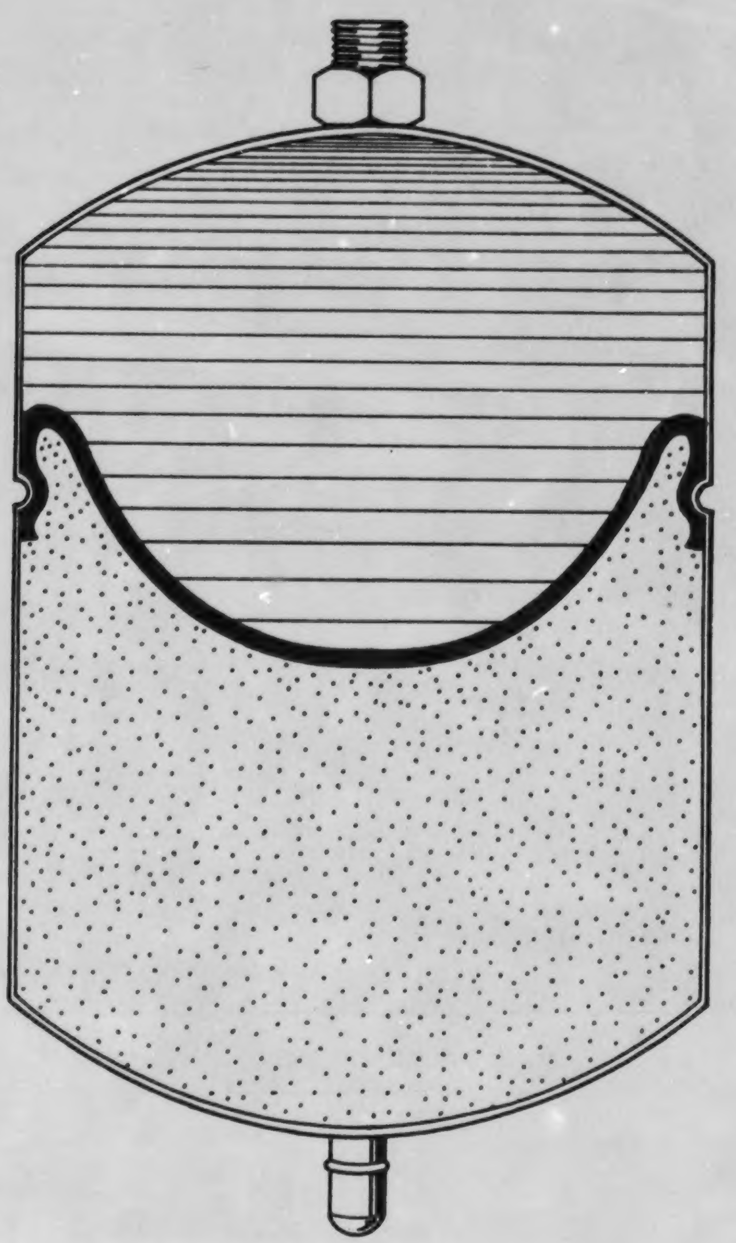
GLOBE VALVE



GATE VALVE

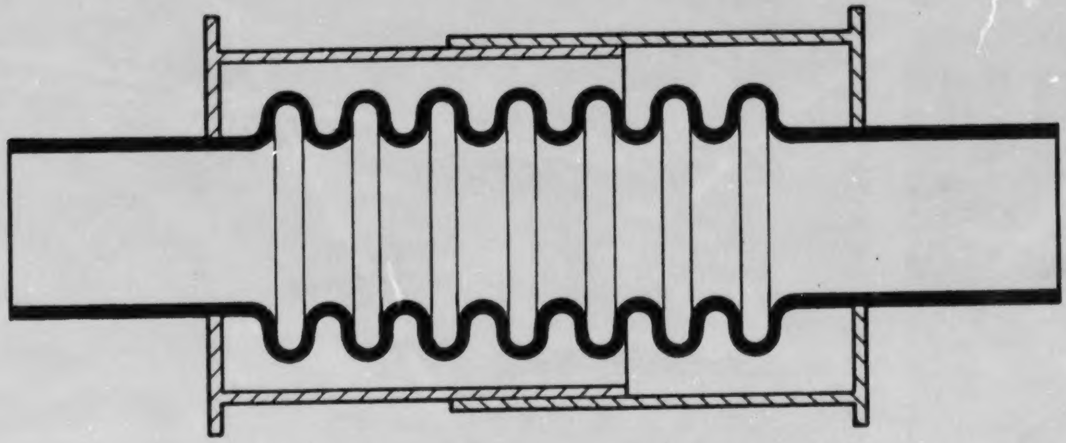


PRESSURE RELIEF VALVE

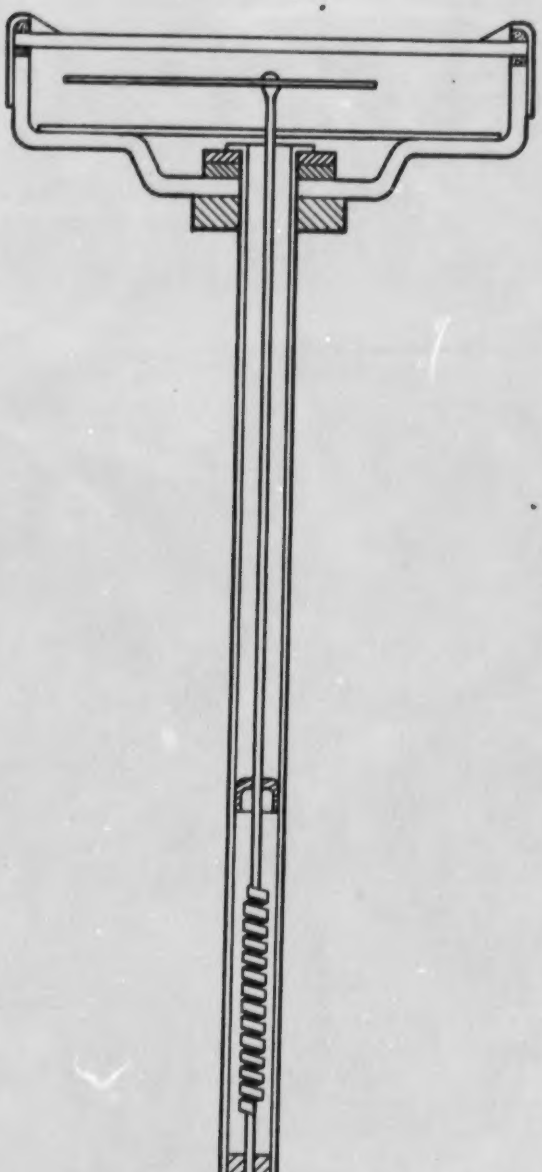


EXPANSION TANK

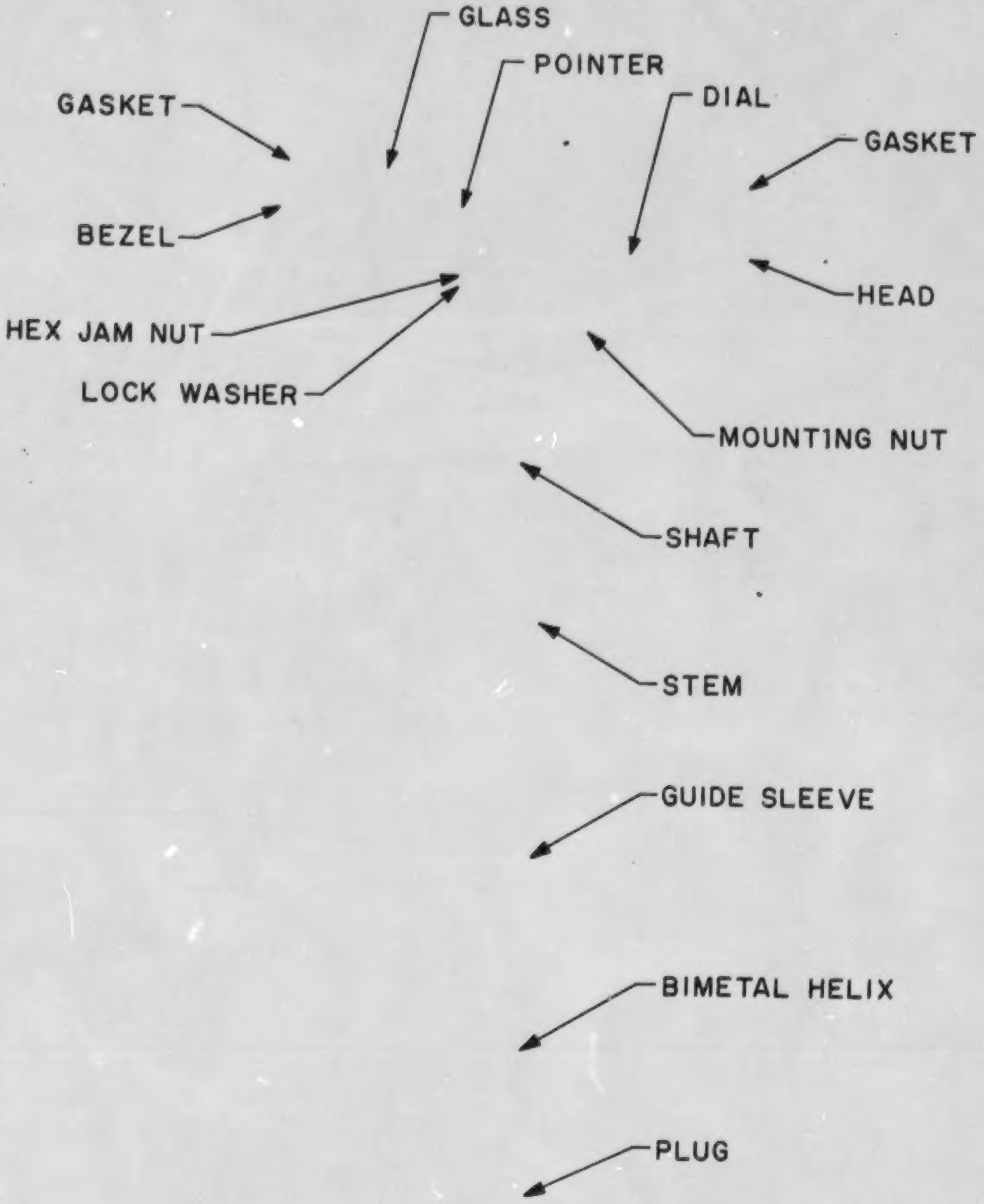
TRANSPARENCY: SYSTEM SIZING, DESIGN AND RETROFIT V-403



THERMAL EXPANSION/CONTRACTION COMPENSATOR



BIMETAL THERMOMETER


GLASS
POINTER
GASKET
DIAL
GASKET
BEZEL
HEAD
HEX JAM NUT
LOCK WASHER
MOUNTING NUT
SHAFT
STEM
GUIDE SLEEVE
BIMETAL HELIX
PLUG

BIMETAL THERMOMETER

COMPONENT LABELS

COLLECTORS AND ENERGY STORAGE

Semester Hours Credit: 4
Lecture: 2
Lab: 4

Project Director:	Charles G. Orsak, Jr.
Prime Author:	H. Alan Boyd
Graphics:	Carole Mitchell
Contributing Authors:	Bob Takacs Everet W. Bolin Norm Abell

Materials developed by
Navarro College
in cooperation with
The National Science Foundation
Project No. SED 80-19327.

INTRODUCTION:

This course introduces the student to the basic information needed for solar system design. It is comprised of a mixture of basic heat transfer theory with application, fluid mechanics theory with application, basic solar hardware description and specifications, basic solar system schematics, and simplified solar sizing procedures for solar heated domestic hot water. Both active and passive solar systems are treated.

This course is a pre-requisite to System Sizing, Design and Retrofit and Non-Residential Applications and Future Technology.

PRE-REQUISITES:

(1) Technical Math I (Algebra & Trigonometry)

(2) Energy Science I (Heat Transfer, Thermodynamics, Fluids)

(3) Introduction to Solar Energy

OBJECTIVES:

Upon completion of this course, the student should be able to:

(1) Analyze and compare the construction and heat transfer characteristics of flat plate and concentrating collectors, both liquid and air.

(2) Determine optimum solar collector orientation and siting.

(3) Write general product specifications for collectors, storage units, heat exchangers, and associated hardware.

(4) Determine the optimum system size and an acceptable configuration (including controls) for a given load.

COLLECTORS AND ENERGY STORAGE

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Key......................................VI-139

Basic Solar Systems - Post-Test.................VI-141
Key......................................VI-145

Hydronic System Components - Post-Test..........VI-147
Key......................................VI-151

Heat Exchangers - Post-Test.....................VI-153
Key......................................VI-157

Heat Transfer Fluids - Post-Test................VI-161
Key......................................VI-165

Air Distribution Components - Post-Test.........VI-167
Key......................................VI-171

Controls and Control Devices - Post-Test........VI-173
Key......................................VI-177

Basic DHW Sizing - Post-Test....................VI-179
Key......................................VI-183

TRANSPARENCY MASTERS.................................VI-187

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Trace the flow of solar energy from source to load, indicating a variety of possible modes.

(2) Summarize the historical development of thermal solar collectors, both active and passive.

(3) Identify and define generic thermal solar collector and solar system types.

REFERENCES:

(1) Montgomery, Richard H., with Jim Budnick, The Solar Decision Book, John Wiley & Sons, 1978.

(2) Kreith, Frank, and Jan F. Kreider, Principles of Solar Engineering, McGraw-Hill, 1978.

(3) Buckley, Shawn, Sun Up to Sun Down, McGraw-Hill, 1979.

(4) A.I.A. Research Corp., Solar Heating and Cooling Demonstration Program A Descriptive Summary of HUD Cycle III Solar Residential Projects, U.S. Dept. of Housing and Urban Development, 1977.

(5) Anderson, Bruce, Solar Energy Fundamentals in Building Design, McGraw-Hill, 1977.

(6) Kreider, Jan F., and Frank Kreith, Solar Heating and Cooling, McGraw-Hill, 1977.

(7) Meinel, Aden B., and Marjorie P. Meinel, Applied Solar Energy - An Introduction, Addison Wesley, 1977.

(8) Williams, J. Richard, Solar Energy Technology and Applications, Revised Ed., Ann Arbor Science, 1977.

(9) McDaniels, David K., The Sun Our Future Energy Source, John Wiley & Sons, 1979.

(10) Michels, Tim, Solar Energy Utilization, Van Nostrand Reinhold Company, New York, 1979.

UNIT TITLES:

(1) Solar Energy Flow Pattern

(2) Solar Energy Conversion Schemes

(3) Historical Developments

(4) Generic Types of Solar Thermal Collectors

(5) Active and Passive Solar Systems

VOCABULARY:

Energy
Collector
Concentrating Collector
Storage
Passive System
Photovoltaic Conversion
Solar Energy
Flat Plate Collector
Tubular Collector
Active System
Thermal Conversion
Biological Conversion

Reference 1, 5

Unit 1. Solar Energy Flow Patterns (For Both Natural and Technological Schemes)

A. Sun - the source
B. The role of collector
C. The role of storage
D. The load or work output

Reference 2, 1
3, 1

Unit 2. Solar Energy Conversion Schemes

A. NSF/NASA solar energy conversion flow chart
B. Thermal conversion
C. Photovoltaic conversion
D. Biological conversion
E. Wind energy conversion
F. Ocean energy conversion

Reference 4
5, 1.A
6, 1
7, 1

NOTE TO INSTRUCTOR:
Use Unit 3 sub-topics A-X to make a Vu-graph for overhead projector

Unit 3. Historical Developments

A. 470-399 BC: Socrates
B. 212 BC: Archimedes
C. 1100 AD: Passive Structures American Indians
D. 1695: Averni and Targioni
E. 1651-1700: Ehrenfried von Tschirnhans
F. 1707-1788: Buffon
G. 1740-1799: Saussare
H. 1743-1794: Lavoisier
I. 1813-1898: Bessemer
J. 1864-1878: Mouchat
K. 1878-1882: Pifre
L. 1871-1884: Ericsson
M. 1878: Adams
N. 1874: Solar Still at Las Salinas, Chile
O. 1902-1918: Willsie & Boyle
P. 1904: Father Himilaya
Q. 1906-1917: Shuman & Boys
R. 1934: Crystal House, Chicago World's Fair
S. 1939-1956: Cabot Solar Energy Conversion Project, M.I.T.
T. 1949: Telkes-Raymond-Peabody House
U. 1957: Lof House
V. 1959: Thomason House
W. 1956: Trombe/Michel
X. 1954: Bell Telephone Laboratories photovoltaic cell

Reference 8, 3
7, 12, 5, 6, 7
2, 4
6, 3
10, 3

Unit 4. Generic Types of Solar Thermal Collectors

- A. Flat plate collector - definition and graphics
- B. Tubular collector - definition and graphics
- C. Concentrating collector - definition and graphics
  - 1. Reflecting
  - 2. Refracting

NOTE: See graphics in Flat Plate and Concentrators Modules at end of course.

Reference 2, 6
6, 4
10, 3

Unit 5. Active and Passive Solar Systems

- A. Active solar systems - defined
- B. Active solar systems - diagrammatic example
  - 1. Domestic hot water
  - 2. Space heating and cooling
- C. Passive solar systems - defined
- D. Passive solar systems - diagrammatic example
  - 1. Domestic hot water (schematic example)
  - 2. Space heating and cooling (schematic example)

NOTE: See graphics for Basic Solar Systems Module at end of course.

STUDENT ACTIVITY	Assignment:
Exercise 1	Outside of class, students should make a block diagram indicating the flow of energy from the sun to the load for each of the conversion schemes listed in Unit 2. Students should indicate the source, collector, storage, and load in each diagram.
Exercise 2	Students should take self test on history of solar thermal devices.
LAB EXERCISE I	On a field trip, students should recognize, identify, and report on the type and location of four solar collector or system types.

MODULE: SOLAR ENERGY CHARACTERISTICS

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Describe the origins and characteristics of solar energy.

(2) Discuss sun/earth relationships.

(3) Determine appropriate sun/collector relationships.

(4) Identify solar radiation measurement equipment.

(5) Select an appropriate source for solar radiation data.

REFERENCES:

(1) McDaniels, David K., The Sun: Our Future Energy Source, John Wiley & Sons, 1979.

(2) Duffie, John A., and William A. Beckman, Solar Energy Thermal Processes, John Wiley & Sons, 1974.

(3) Mazria, Edward, The Passive Solar Energy Book, Rodale Press, Inc., 1979.

(4) Meinel, Aden B., and Marjorie P. Meinel, Applied Solar Energy: - An Introduction, Addison Wesley, 1977.

(5) Howell, Yvonne, and Justin A. Bereny, Engineer's Guide to Solar Energy, Solar Energy Information Services, 1979.

(6) Michels, Tim, Solar Energy Utilization, Van Nostrand Reinhold Company, New York, 1979.

UNIT TITLES:

(1) Origin and Characteristics of Solar Energy

(2) Sun/Earth Relationships

(3) Sun/Collector Relationships

(4) Solar Radiation Measuring Equipment

(5) Sources of Solar Radiation Data

VOCABULARY:

Solar Constant

Beam Radiation (Direct Radiation)

Diffuse Radiation

Total Radiation

Air Mass

Solar, or Short-wave Radiation

Non-tracking Collector

Long-wave Radiation

Pyranometer

Absorption

Solar Time

Inverse Square Law

Altitude

Azimuth

Zenith

Sun Angle

Tracking Collector

Insolation

Pyraheliometer

Light Spectrum

Frequency

Wave Length

Diurnal

Reference 4, 5, 6
1, 25, 2
11, 2
27, 2
2, 24
1, 22

Unit 1. Origin and Characteristics of Solar Energy
- A. Solar fusion of hydrogen
- B. Blackbody radiator at 6000° K
- C. Solar constant
- D. Wavelength vs. solar intensity of solar radiation
  - 1. Ideal blackbody radiator
  - 2. Outside the earth's atmosphere
  - 3. Air mass ratio
  - 4. Absorption bonds in atmosphere
- E. Solar and visible spectrum compared to known electromagnetic spectrum
- F. Types of radiation
  - 1. Beam (direct)
  - 2. Diffuse (scattered)
  - 3. Total (global)
- G. Calculation of solar time

Reference 6, 2
2, 2
3, 2
4, 3

5, 2

Unit 2. Sun/Earth Relationships
- A. Orbital radius variations
- B. Seasonal variation (attached graphic at end of course)
  - 1. Summer solstice
  - 2. Autumnal equinox
  - 3. Winter solstice
  - 4. Spring equinox
  - 5. Solar altitude
  - 6. Azimuth
  - 7. Zenith
- C. Daily (diurnal) variations
  - 1. Effects of air mass (attached graphic at end of course)
  - 2. Cloud cover
  - 3. Pollutants
- D. Calculation of sun angle
- E. Sun path diagrams
- F. Calculation of solar intensity from horizontal radiation measurements

Reference 2, 3
3, 2
4, 2, 3
5, 2

Unit 3. Sun Collector Relationships (Orientation)
- A. South-facing vertical surface (attached graphics)
- B. South-facing horizontal surface

C. South-facing tilted surface
D. Non-south-facing tilted surface

Graphics PA-2,3

e. Rotation about an east-west axis
F. Rotation about a north-south axis
G. Fully tracking

Reference 1
2, 3
4, 2
6, 2

Unit 4. Solar Radiation Measuring Equipment
- A. Pyranometer
  - 1. Thermopiles
  - 2. Photovoltaic cells
- B. Shading-ring pyranometer
- C. Pyrheliometer
- D. Moving shadow-box pyrheliometer
- E. Sunshine recorder

Reference 6, A
5, 2

Unit 5. Sources of Solar Radiation Data
- A. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE)
- B. National Weather Service
- C. Climatic Atlas of United States
- D. National Weather Center, Ashville, N.C.

STUDENT ACTIVITY	Assignment:
Exercise I	Self-test on origin and characteristics of solar energy
LAB EXERCISE I	Take-home Lab Determine relationship between altitude, azimuth, and annual variations.
Lab Equipment:	See Attached Drawings (Appendix pp. 4-6, Drawing No. L-3, pp. 1-3).
Lab Procedure:	See attachment (Appendix pp. 1-3)
LAB EXERCISE II	Use a pyranometer to take measurements and compare to expectations from Unit 2-F.
Lab Equipment:	Pyranometer with variable angle mounting Protractor Recording equipment
Lab Procedure:	(1) Make insolation measurements at horizontal 30° above horizontal facing solar south, 60° above horizontal facing

south, and vertical facing south (clear day measurements).

(2) Use methods from Unit 2-F to calculate expected values of insolation for 30° 60°, 90°

(3) Compare actual measurements, calculations, and data from solar radiation tables.

MODULE: HEAT TRANSFER REVIEW VI-17

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Solve simple problems relating to conduction, convection, and radiation heat transfer.

(2) Discuss methods of enhancing or retarding heat transfer.

REFERENCES:

(1) Buckley, Shawn, Sun up to Sun Down, McGraw-Hill, 1979.

(2) Tippens, Paul E., Applied Physics, 2nd Ed., McGraw-Hill, Dallas, 1978.

(3) Kreith, Frank and Jan F. Kreider, Principles of Solar Engineering, McGraw-Hill, 1978.

(4) Meinel, Aden B., and Marjorie P. Meinel, Applied Solar Energy: - An Introduction, Addison Wesley, 1977.

(5) Holman, J.P., Heat Transfer, 2nd Ed., McGraw-Hill, 1968, OR Other Heat Transfer Text!

(6) Michels, Tim, Solar Energy Utilization, Van Nostrand Reinhold Company, New York, 1979.

(7) Mazria, Edward, The Passive Solar Energy Book, Rodale Press, Inc., 1979.

UNIT TITLES:

(1) Conduction

(2) **Convection**

(3) Radiation

VOCABULARY:

Conduction

Radiation

Thermal Conductivity

Convection Co-efficient

Co-efficient of Heat Transfer

Convection

K-factor

R-factor

U-value

Stefan's Constant

References 3, 3
4, 10
7, 2
2, 19
5, 1
6, F
1, 4

Unit 1. Conduction
- A. Definition
- B. Molecular description of process
- C. Conduction equation with examples, including units
- D. Thermal conductivity of solar applicable materials
  - 1. Steel
  - 2. Aluminum
  - 3. Copper
  - 4. Glass
  - 5. Insulation
  - 6. Rubber
  - 7. Air
  - 8. Wood
  - 9. Water
  - 10. Combinations of materials
- E. Improving conduction heat transfer
  - 1. Increasing temperature differential
  - 2. Increasing area
  - 3. Decreasing thickness
  - 4. Higher thermal conductivity
- F. Retarding conduction heat transfer
  - 1. Decreasing temperature differential
  - 2. Decreasing area
  - 3. Increasing thickness
  - 4. Lower thermal conductivity

References 6, F
5, 1
3, 3
4, 10
7, 2
1, 4
2, 19

Unit 2. Convection
- A. Definition
- B. Molecular description of process
- C. Convection equation with examples, including units
- D. Natural convection
- E. Forced convection
- F. Enhancing heat transfer
- G. Retarding heat transfer

References 6, F
3, 3
4, 10
7, 2
1, 5
2, 19
5, 1

Unit 3. Radiation
- A. Definition
- B. Reflectance, absorptance, transmittance equation with examples
- C. Radiation equation with examples

D. Increasing radiation heat transfer
E. Decreasing radiation heat transfer

STUDENT ACTIVITY

Assignment:

Exercise

Students should solve problems for each form of heat transfer and indicate how heat transfer can be enhanced or retarded for each problem.

LAB EXERCISE I

Determine thermal performance of absorber plate as a function of fin width and relate to heat conduction equation.

Lab Equipment:

Variable collector (or equivalent) with single glazing (see drawings No. L-2, pp. 1-6, Appendix pp. A7-A12)
insulation, two absorber plates with alternate tubing options shown on drawing
hoses
tanks (insulated)
hose fittings
thermometers
solar meter

Lab Procedure:

(1) Allow a specific mass (1 lb. for example) to flow slowly through the tubing on the collector for both absorber tubing configuration options.

(2) Measure the temperature rise and time necessary to flow the volume through. Also measure insolation.

(3) With this information, determine the collector efficiency and the effect of fin width on energy recovered from the collector. Relate to heat conduction equation.

MODULE: FLUID MECHANICS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Determine static pressure head of a piping system.

(2) Convert absolute pressure to gauge pressure.

(3) Analyze the characteristics of Laminar and turbulent flow and the effects on heat transfer.

(4) Calculate rate of fluid flow in tubes.

(5) Determine the Reynolds number for a specific application.

(6) Determine frictional losses in piping systems.

(7) Compare the effect of changes in pipe size, fitting, bends, and valves.

REFERENCES:

(1) Tippens, Paul E., Applied Physics, 2nd Ed., McGraw-Hill, Dallas, 1978.

(2) Kreith, Frank, and Jan F. Kreider, Principles of Solar Engineering, McGraw-Hill, 1978.

(3) Holman, J.P., Heat Transfer, 2nd Ed., McGraw-Hill, 1968.

(4) Carrier Handbook of System Design, McGraw-Hill, New York, 1974.

(5) Montgomery, Richard H., and Jim Budnick, The Solar Decision Book, John Wiley and Sons, 1978.

UNIT TITLES:

(1) Static Pressure

(2) Relationship Between Gauge Pressure and Absolute Pressure

(3) Rate of Flow

(4) Laminar and Turbulent Flow

(5) Frictional Losses in Piping

(6) Other Sources of Circulating Pressure Losses

(7) Total Head Requirements

VOCABULARY:

Fluid Statics

Pressure

Gauge Pressure

Atmospheric Pressure

Laminar Flow

Static Head

Transition Range

Hydrodynamic Boundary Layer

Viscosity

Specific Volume

Total Head

Fluid Dynamics

Fluid

Absolute Pressure

Velocity

Dynamic Head

Turbulent Flow

Reynolds Number

Thermal Boundary Layer

Density

Flow Units

MODULE: FLUID MECHANICS

Reference 1, 15
2, 3

Unit 1. Static Pressure
- A. Define fluid statics
- B. Define pressure
- C. Characteristics of fluid pressure
- D. Fluid pressure as a function of density, and depth
- E. Example problems for water and other fluids

Unit 2. Relationship Between Gauge Pressure and Absolute Pressure
- A. Atmospheric pressure
- B. Gauge pressure
- C. Absolute pressure
- D. Example problems

Unit 3. Rate of Flow (Fluid Dynamics)
- A. Fluid velocity
- B. Tubing cross-section (transverse area)
- C. Examples

Reference 1, 16
2, 3
3, 5

Unit 4. Laminar and Turbulent Flow (Fluid Dynamics)
- A. Laminar
  - 1. Velocity profile for flat plate
  - 2. Velocity profile for tube
- B. Turbulent
  - 1. Velocity profile for flat plate
  - 2. Velocity profile for tube
- C. Transition
  - 1. Range of Reynold's Number for flat plate
  - 2. Range of Reynold's Number for tube
- D. Calculation of Reynold's Number
- E. Hydrodynamic and thermal boundary layers
  - 1. Laminar flow
  - 2. Turbulent flow

Reference 4
5, 12
2, 3

Unit 5. Frictional Losses in Piping Systems (Fluid Dynamics)
- A. Type of pipe
- B. Schematic diagrams and symbols
- C. Frictional losses vs. flow rate graph (flow chart)

D. Examples
E. Closed System Considerations

Reference 5, 12
2, 3

Unit 6. Other Sources of Circulating Pressure Losses
A. Fittings
B. Valves
C. Bends
D. Changes in pipe size
E. Equipment losses

Reference 5, 12
2, 3

Unit 7. Total Head Requirements
A. Static head
B. Dynamic head
C. Pumping requirements

STUDENT ACTIVITY

Assignment:

Exercise I

Student should solve problems relating to static pressure head, absolute vs. gauge pressure (compression ratios), rate of fluid flow in tubes, and Reynold's Number.

Exercise II

Outside the Classroom

Given a piping schematic, friction loss flow diagram equivalent feet of pipe chart for fittings, equipment loss, application including fluid and g.p.m. requirements, the student should:

(1) Select the correct pipe size for each area of the piping run.

(2) Specify the pump requirements for the application.

Lab Exercise I:

Using a simple counterflow tube in tube heat exchanger, determine heat transfer rate as a function of Reynold's Number (relate Reynold's Number to Laminar and turbulent flow).

Lab Equipment:

Source of Hot Water
Source of Cold Water
2 temperature monitors (± .2° F)
(Thermocouples and Data logger)
Straight "tube in tube" counter flow heat exchanger made from copper tubes and fittings
Hoses
Flow meter (0-2.56 pm)

Lab Procedure:

(1) While monitoring the temperature of the inlet and outlet of the constant flow of the cold fluid going through the outer tube, make discrete changes in the flow rate of the hot fluid going through the inner tube.

(2) At each flow setting allow the system to stabilize thermally and record temperatures going in and out of outer tube.

(3) Note the change in the temperature difference of the entering and leaving cold water as a function of flow rate of the hot water.

(4) Compare the rate of change in temperature difference with the calculated Reynold's Number.

(5) Determine the relationship of fluid velocity, Reynold's Number, Laminar or turbulent flow, and heat transfer.

MODULE: FLAT PLATE COLLECTORS

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Compare and contrast flat plate collector construction options and their associated heat transfer properties.

(2) Describe standardized thermal testing procedures and associated efficiency curves applicable to flat plate collectors.

(3) Write a general and/or specific flat plate collector specification.

(4) Apply rules of thumb for siting flat plate collectors.

(5) Compare passive architecture and flat plate collectors.

REFERENCES:

(1) Buckley, Shawn, Sun Up to Sun Down, McGraw-Hill, 1979.

(2) Montgomery, Richard H., with Jim Budnick, The Solar Decision Book, John Wiley & Sons, 1978.

(3) Kreider, Jan F., and Frank Kreith, Solar Heating and Cooling, McGraw-Hill, 1977.

(4) Howell, Yvonne, and Justin A. Bereny, Engineer's Guide to Solar Energy, Solar Energy Information Services, 1979.

(5) Duffie, John A., and William A. Beckman, Solar Energy Thermal Processes, John Wiley & Sons, 1974.

(6) Kreith, Frank, and Jan F. Kreider, Principles of Solar Engineering, McGraw-Hill, 1978.

(7) Meinel, Aden B., and Marjorie P. Meinel, Applied Solar Energy - An Introduction, Addison Wesley, 1977.

(8) U.S. Dept of Housing & Urban Development, HUD Intermediate Minimum Property Standards Supplement - Solar Heating and Domestic Hot Water Systems, H.U.D., 1977, 4930.2.

(9) Solar Energy Applications Laboratory, Colorado State University, Solar Heating and Cooling of Residential Buildings - Sizing Installation and Operation of Systems, U.S. Dept. of Commerce, 1977.

(10) ASHRAE Standard 93-77, Methods of Testing to Determine the Thermal Performance of Solar Collectors, ASHRAE, NY.

(11) Michels, Tim, *Solar Energy Utilization*, Van Nostrand Reinhold Company, New York, 1979.

UNIT TITLES:

(1) Introduction (Definition, Advantages)

(2) Classification

(3) Construction - General

(4) Absorber

(5) Glazing

(6) Insulation

(7) Collector Enclosure

(8) Energy Balance/Efficiency

(9) Specifications

VOCABULARY:

Collector

Glazing

Insulation

Seals

Transmittance

Gross Area

ASHRAE

Angle of Incidence

Flat Plate Collector

Absorber

Absorptivity

Emissivity

Reflectance

Aperture Area

HUD

R-Value

Reference 2, 10 5, 7 11, 3 7, 12 1, 11	Unit 1. Introduction A. Define collector B. Define flat plate collector c. Outstanding characteristics of flat plate collectors
Reference 2, 10 11, 3 7, 12 9, 11 Graphics (Appendix) FP-2, 3	Unit 2. Classification (Graphics) a. Liquid or air B. Number of glazing c. Absorber coating D. Operating temperature E. Application
Reference 2, 10 9, 11 11, 3 7, 12 5, 7 Graphics (Appendix) FP-1,2-B,3-B	Unit 3. Flat Plate Construction - General (Graphic Attached) A. Absorber plate B. Glazing - seals C. Insulation D. Collector box
Reference 2, 10 6, 4 7, 12 3, 3 5, 7 8, B 9, 11 Graphics (Appendix) FP-2, 3	Unit 4. Absorber A. Heat transfer considerations 1. Radiation 2. Conduction 3. Convection B. Absorption surface 1. Non-selective 2. Selective 3. Heat transfer C. Liquid absorber plates 1. Flow patterns/ construction 2. Materials 3. Heat transfer 4. Advantages/disadvantages D. Air absorber plates 1. General construction/ flow patterns 2. Materials 3. Heat transfer 4. Advantages/disadvantages
Reference 2, 10 3, 3 6, 4 8, B 7, 12 9, 11 Graphics (Appendix) FP-2,3-A,C	Unit 5. Glazing A. Energy transfer through glazing 1. Radiation a. Transmittance as a function of angle of incidence b. Absorptance c. Reflectance as a function of angle of incidence

B. Glazing options
C. Gaskets and seals
D. Optical properties
E. Mechanical properties
F. Chemical properties
G. Seals
H. Maintenance/replacement
I. Availability

Reference 2, 10
9, 11

Unit 6. Insulation
A. R-Valve, heat transfer considerations
B. Collector environment constraints
C. Materials

Reference 2, 10

Unit 7. Collector Enclosure
A. Design/selection considerations
B. Heat transfer

Reference 2, 10
7, 12
1, 11
3, 3
8, 6
9, 11
10
Graphics (Appendix)
FP-2,3-C,D,E

Unit 8. Energy Balance and Collector Efficiency (Graphics Attached)
A. Define efficiency
B. Graphics on "energy in - energy out" in flat plate
C. Standardized collector thermal testing
    1. ASHRAE 93-77
    2. HUD INTERMEDIATE MINIMUM PROPERTY STANDARDS, Solar Heating & Domestic Hot Water, 1977 Edition (4930.2)
D. Efficiency curves/collector types

Reference 2, 10
8, 6

Unit 9. Specifications
A. General
    1. Collector type
    2. Size constraints
    3. Manifold/piping constraints
    4. Efficiency constraints
    5. Construction constraints
    6. Warranty constraints
    7. Mounting constraints
    8. Pressure constraints
B. Specific (manufacturer's specifications)

STUDENT ACTIVITY

Exercise

Assignment:

(1) Students should self-test on characteristics, classification, and components of collector.

(2) Outside class students will draw a cross-section of a flat plate collector and with diagrams and labels indicate the heat gains and losses associated with flat plate collectors.

(3) Students should list the absorber plate options and discuss the associated heat transfer considerations and the advantages and disadvantages.

(4) Students should list glazing options with their characteristics and applications.

(5) Students should list insulation options with associated advantages and disadvantages.

(6) Students should list collector housings and materials of manufacturer.

(7) Students should write specifications for collectors.

LAB EXERCISE I

Determine the absorption and reflection as a function of number of glazings and of Angle of Incidence.

Lab Equipment:

Variable Collector or equivalent (See Drawing No. L-2, pp. 1-6 in Appendix, pp. A7 - A12)
Silicon cell
At least three glass glazings
Milliamp meter

Lab Procedure:

(1) With the silicon cell attached to the absorber plate of the collector, assemble with all glazings and absorber in place.

(2) Use the milliamp meter to measure no load amperage output of cell with all variations of number of glazings and no glazing with the collector (1) normal to sun; (2) 30° off-normal to sun; and, (3) 60° off-normal to sun.

(3) Analyze data to determine °/o of available light which actually strikes the surface of the absorber under conditions of increasing number of glazing and increasing angle of incidence.

LAB EXERCISE II: Determine effects of number of glazings and absorption surface on thermal performance of flat plate collector.

Lab Equipment:

Variable collector or equivalent (including at least three glazings, several absorber plates with a variety of coating colors (also selective and insulation) (See Drawing No. L-2, pp. 1-6 in Appendix, p. A-7 - A12)
Two temperature monitoring probes
Insolation meter

Lab Procedure:

(1) Arrange monitoring equipment to measure ambient temperature, absorber plate temperature, and insolation (measured normal to direct radiation).

(2) With the collector normal to the sun and staring with the absorber at ambient temperature, record temperatures at absorber plate and air, and record insolation at one minute intervals as the temperature in the collector increases to stagnation. Repeat this procedure for variations in number of glazings and variations in absorber surface.

(3) Analyze data to determine the effect of absorber coating, the effect of glazings, and the effect of insulation on thermal performance of collector.

LAB EXERCISE III: (OPTIONAL) Using procedures and equipment similar to those outlined in ASHRAE 93-77, students will produce an efficiency curve for a flat plate collector.

Lab Equipment:

Pyronometer
Calibrated and matched type T thermocouples
Data Logger
Accurate flow meter
Wind speed and direction recording devices
Collector
Circulating pump and heat-exchanger (see illustration p. 8, ASHRAE Standard 93-77)

Lab Procedure:

Measure the following variables at four "temperature of inlet fluid minus temperature of ambient" conditions

(i.e., $t_{fi} - t_a = 0$,

$t_{fi} - t_a = 20\text{-}30^\circ F$

$t_{fi} - t_a = 40\text{-}60^\circ F$

$t_{fi} - t_a = 60\text{-}80^\circ F$

ambient temperature (t_a) (^oF)

collector fluid inlet temperature (t_{fi}) (^oF)

collector fluid outlet temperature (t_{fe}) (^oF)

insolation rate in the plane of the collector

aperture (I_A) (BTU/hr-ft.^{2})

flow rate (ṁ) (lbm/hr)

Also measure

gross area of collector

specific heat of transfer fluid

Use the data to plot a curve of collector efficiency (n) as a function of the temperature difference/Insolation Parameter where

$$n = \frac{\dot{m}\ cp\ (T_{fe} - t_{fi})}{A_g\ I_t}$$

Temperature difference/Insolation parameter =

$$\frac{t_{fi} - t_a}{I}$$

(See illustration Page 20, ASHRAE Standard 92-97)

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Evaluate concentrating collector optical systems in terms of the relationship between concentration ratio and acceptance angle.

(2) Compare and contrast receiver design concepts.

(3) Analyze the relationship between construction and efficiency curve expectations for concentrating collectors.

(4) Identify materials commonly used in construction of concentrating collectors.

(5) Explain basic tracking system logic and hardware.

(6) Discuss appropriate applications for concentrating collectors.

REFERENCES:

(1) Kreith, Frank, and Jan F. Kreider, Principles of Solar Engineering, McGraw-Hill, 1978.

(2) Meinel, Aden B., and Marjorie P. Meinel, Applied Solar Energy: - An Introduction, Addison Wesley, 1977.

(3) Montgomery, Richard H., with Jim Budnick, The Solar Decision Book, John Wiley & Sons, 1978.

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MODULE: CONCENTRATING COLLECTORS

UNIT TITLES:

(1) Introduction

(2) Classifications

(3) Receiver Design

(4) Heat Transfer

(5) Tracking Systems

(6) Concentrator Geometry

(7) Manufacturing Materials

(8) Applications for Concentrators

(9) Concentrator Efficiency

VOCABULARY:

Concentrating Collector
Tubular Collector
Winston Collector
Shadow Bar
Tracking
Imaging
Trough
Circular
Concentration Ratio
Deviation Angle
Parasitic Losses
Alzak Reflective Aluminum
Focus
Focal Area

Vacuum Tube Collector
Compound Parabolic (CPC)
Parabolic
Receiver
Non-Tracking
Non-Imaging
Dish
Aperture
Acceptance Angle
Tracking Control
Sagged Glass
FEK
Focus Point

Reference 5, 8
6, 3
1, 4

Unit 1. Introduction
- A. Definition
- B. Outstanding characteristics

Reference 1, 4
3, 10
5, 8
6, 3
2, 5, 6, 7
8, 4
Graphics (Appendix)
CO-1 - CO -6

Unit 2. Classification (Graphics Attached)
- A. Non-tracking or seasonally adjusted
  - 1. Mirror augmented flat plate
  - 2. Compound Parabolic Collectors (CPC)
  - 3. V-trough
- B. Single axis tracking
  - 1. Parabolic trough
  - 2. Fresnel lens
  - 3. Fresnel mirror
  - 4. Fixed mirror moving receiver
- C. Dual axis and tracking
  - 1. SRTA (Stationary Reflector, Tracking Absorber)
  - 2. Parabolic dish
  - 3. Central receiver

Reference 6, 3
1, 4

Unit 3. Receiver Design
- A. Tubular collectors
  - 1. Design variations
  - 2. Applications
  - 3. Efficiency
  - 4. Advantages/disadvantages
- B. Central Receiver

Reference 5, 8
2, 11
1, 3, 4

Unit 4. Heat Transfer
- A. Radiation
  - 1. Reflection losses
  - 2. Absorption losses
  - 3. Re-radiation losses
- B. Conduction
- C. Convection

Reference 1, 4

Unit 5. Tracking Systems
- A. Non-tracking
- B. Occasional manual adjustment
- C. Single axis
- D. Dual axis
- E. Hardware
- F. Problems encountered

Reference 5, 8
1, 4

Unit 6. Concentrating Geometry
- A. Aperture
- B. Concentration ratio
- C. Acceptance angle

Reference 5, 8 2, 8	Unit 7. Manufacturing Materials A. Reflecting surfaces B. Refracting material C. Receiver
Reference 6, 3 1, 4 8, 4	Unit 8. Applications For Concentrators A. Residential B. Commercial C. Industrial
Reference 5, 8 1, 4	Unit 9. Concentrator Efficiency A. Non-tracking B. Single axis tracking C. Dual axis tracking

STUDENT ACTIVITY

Assignment:

Exercise

Outside classroom, student should self-test on the following items:

Collector definition
Outstanding characteristics of concentrating collectors
Classification
Advantages and disadvantages of each classification
Heat transfer characteristics at reflecting or refracting component and at the receiver
Materials of construction
Receiver design
Tracking logic and hardware
Applications
Concentrator efficiency
Tubular collector design
Tubular collector advantages
Tubular collector disadvantages
Tubular collector applications
Tubular collector efficiency

LAB EXERCISE I:

Students will determine thermal consequences of reflectivity of mirrored surfaces on concentrating collectors.

Lab Equipment:

Parabolic trough unit [see Drawing No. L-1, pp. 1-4 (Appendix 4, pp. A14-A16)] with at least three reflective surface options (i.e., reflective aluminum, stainless steel, polished aluminum.)
Temperature monitoring equipment
Solar meter
Wind speed monitor
Timing device

Lab Procedure:

(1) With receiver in place and starting at ambient temperature, record the temperature increase as a function of time (at one minute intervals until stagnation) for each type of reflecting surface. Also record ambient temperature, insolation, and wind speed at one minute intervals.

(2) Plot the difference in temperature between the receiver and ambient as a function of time for each reflective surface and analyze.

LAB EXERCISE II:

Determine thermal effects of receiver optical system.

Lab Equipment:

Parabolic trough unit [see Drawing No. L-1, pp. 1-4 (Appendix, pp. A14-A16)] with receiver and cylindrical glazing
Temperature monitoring equipment
Solar meter
Timing device

Lab Procedure:

(1) Determine and record temperature difference between receiver (with and without cylindrical glazing) and ambient at one minute intervals. Also record insolation data at the same intervals.

(2) Graph both sets of data on the same set of axis and analyze.

LAB EXERCISE III:

Students should determine acceptance angle and concentration ratio relationships for parabolic reflectors, compound parabolic reflectors, circular reflectors, and fresnel lens.

Lab Equipment:

Approximately 1" thick cross-sections of:

(1) compound parabolic reflector
(2) parabolic reflector
(3) circular reflector
(4) Fresnel lens

Various sized receiver cross-sections 1" thick
Compass

Lab Procedure:

(1) For each concentrating segment/receiver segment combination, determine the best focal point, the concentration ratio, and the maximum angle of deviation to both the east and west of the best focus. This can be done by laying the segments on a piece of cardboard and marking the extremities of deviation angles.

(2) Analyze the resulting data to determine trends in concentration ratio/acceptance angle relationships for each type of cross-section.

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Compare and contrast construction options for liquid and air storage.

(2) Sketch a graph depicting the daily thermal cycle in thermal storage unit.

(3) Identify passive architecture storage methods.

REFERENCES:

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(2) Christensen, David L., Solar Energy for Buildings Handbook, U.S. Dept. of Energy, 1979, ORO-5362-T1.

(3) Duffie, John A., and William A. Beckman, Solar Energy Thermal Processes, John Wiley & Sons, 1974.

(4) Meinel, Aden B., and Marjorie P. Meinel, Applied Solar Energy - An Introduction, Addison Wesley, 1977.

(5) U.S. Dept. of Housing & Urban Development, HUD Intermediate Minimum Property Standards Supplement - Solar Heating and Domestic Hot Water Systems, H.U.D., 1977, 4390.2.

(6) Kreider, Frank, and Frank Kreith, Solar Heating and Cooling, McGraw-Hill, 1977.

(7) Ehrenkrantz Group, P.C. and Mueller Associates, Inc., Active Solar Energy System Design Practice Manual, U.S. Dept. of Energy, 1979, Solar 1082-79/01.

(8) Solaron Engineering Application Manual for Air Systems, Solaron Energy Corp., 1979.

(9) Cole. Roger L., et al, Design & Installation Manual for Thermal Energy Storage, U.S. Dept. of Energy, 1980, ANL-79-15.

(10) Solar Energy Applications Laboratory, Colorado State University, Solar Heating and Cooling of Residential Buildings - Sizing Installation and Operation of Systems, U.S. Dept. of Commerce, 1977, Stock No. 003-011-00085-2.

(11) Mazria, Edward, The Passive Solar Energy Book, Rodale Press, Inc., 1979.

(12) Montgomery, Richard H., with Jim Budnick, The Solar Decision Book, John Wiley & Sons, 1978.

(13) Howell, Yvonne, and Justin A. Bereny, *Engineer's Guide to Solar Energy*, Solar Energy Information Services, 1979.

UNIT TITLES:

(1) Introduction

(2) Classification and Rules of Thumb for Thermal Storage

(3) Thermal Considerations

(4) Construction Materials and Specifications

(5) Storage Location

(6) Other Storage Options

VOCABULARY:

Storage

Thermal Storage

Chemical Storage

Sensible Heat

Latent Heat

Phase Change

Eutectic Salts

Liquid Storage

Rock Storage

Thermal Mass

Reference 1, 6
9, 1   6, 5
3, 9   10, 6

Unit 1. Introduction
A. Define storage
B. Collector, storage, load relationships

Reference 6, 5
11, 2
13, 5
10, 6
9, 1
3, 9

Unit 2. Classification and Rules of Thumb for Thermal Storage
A. Sensible heat storage
1. Define
2. Water
3. Rock
4. High temperature liquids
B. Latent heat
1. Define
2. Eutectic salts
C. Air storage
D. Liquid storage
E. Thermal mass storage (passive architecture)

Reference 11, 2
1, 6
13, 5
10, 6
9, 1, 2, 3
3, 9
4, 13

Unit 3. Thermal Considerations
A. Liquid
1. Insulation/rate of heat loss
2. Stratification
a. Enhancement
b. Degradation
3. Temperature gradient/daily performance
4. Heat capacity/storage capacity
B. Air
1. Insulation/rate of heat loss
2. Stratification
a. Enhancement
b. Degradation
3. Temperature gradient/daily performance
4. Heat capacity/storage capacity
C. Thermal mass storage
1. Insulation/rate of heat loss
2. Temperature gradient/daily performance
3. Heat capacity/storage capacity

Reference 12, 14
6, 5
11, 2
10, 6
9, 3

Unit 4. Construction Materials
A. Liquid
1. Steel
A. Advantages
b. Disadvantages

2. Fiberglass
   a. Advantages
   b. Disadvantages
3. Concrete
   a. Advantages
   b. Disadvantages
4. Wood
   a. Advantages
   b. Disadvantages
5. Elastometric fabrics
   a. Advantages
   b. Disadvantages
6. Insulation options
   a. Advantages
   b. Disadvantages

B. Air
   1. Wood housing unit
   2. Concrete housing unit

C. Thermal mass
   1. Masonry
   2. Water wall
   3. Other

Reference 9
13, 5
10, 6

Unit 5. Storage Location
A. Load requirements
B. Length of plumbing/duct runs
C. Generally available sheltered locations
   1. Basements
   2. Crawlspace
   3. Garage
   4. Outdoors, above grade
   5. Outdoors, below grade

Reference 3, 9
13, 5
4, 13

Unit 6. Other Storage Options
A. Chemical
B. Compressed air

STUDENT ACTIVITY

Exercises

Assignment:

Students should classify active storage units as sensible or latent and as liquid or air.

Students should list passive architecture storage methods.

As a take-home assignment, students should sketch sketch and explain temperature profiles in storage units at various stages of a daily cycle.

Students should write from memory the heat capacities of water and rocks and compare storage capacity per unit volume.

Students should, on a test, list construction material options with associated advantages and disadvantages.

Given a specific site condition, the student should select the proper location for the storage unit.

Students should self-test outside classroom on storage options.

LAB EXERCISE I: Students should monitor the temperature profiles in a rock storage unit through a complete charge and discharge cycle and report results.

Lab Equipment: Appropriately sized rock storage unit with associated air collectors, ducting and controls (including thermocouples in storage)
Data Logger with Type T thermocouples

Lab Procedure:

(1) Begin recording data early in the morning at 1/4 hour intervals with the storage unit completely discharged.

(2) Continue to take data while the storage unit charges for a full day.

(3) Allow the unit to sit overnight while taking data.

(4) Take data while storage unit discharges.

(5) Make temperature profile graphs and analyze.

LAB EXERCISE II: Students should monitor temperature profiles in a liquid storage unit through a complete charge and discharge cycle and report results.

Lab Equipment: Appropriately sized liquid storage unit with associated liquid collectors, piping and controls (including thermocouples in storage)
Data logger with Type T thermocouples

Lab Procedure: Same as Lab Exercise I

LAB EXERCISE III:	Students should monitor temperature profiles in a phase charge storage unit through a complete charge and discharge cycle and report results.
Lab Equipment:	Appropriately sized phase charge storage unit with appropriate collectors and fluid transport equipment and controls (including type T thermocouples) Data logger
Lab Procedure:	Same as Lab Exercise I

MODULE: BASIC SOLAR SYSTEMS

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Compare and contrast basic system configurations, including the necessary hydronic hardware.

(2) Describe freeze control methods.

(3) Discuss general control logic.

REFERENCES:

(1) Franklin Research Center, Installation Guidelines for Solar DHW Systems in One- and Two-Family Dwellings, U.S. Dept. of Housing and Urban Development, 1980.

(2) Solar Energy Applications Laboratory, Colorado State University, Solar Heating and Cooling of Residential Buildings - Sizing Installation and Operation of Systems, U.S. Dept. of Commerce, 1977, Stock No. 003-011-00085-2.

(3) Beckman, William A., et al, Solar Heating Design by the f-Chart Method, John Wiley & Sons, 1977.

(4) Solar Heating System Design Manual, ITT Training & Education Dept. Fluid Handling Division, 1977.

(5) Chandra, Subrato, et al, Solar Water and Pool Heating and Installation and Operation, Florida Solar Energy Center, 1979.

(6) Root, Douglass E., Jr., et al, Solar Heating for Swimming Pools, Florida Conservation Foundation, Inc., 1980.

(7) Duffie, John A., and William A. Beckman, Solar Energy Thermal Processes, John Wiley & Sons, 1974.

(8) Howell, Yvonne, and Justin A. Bereny, Engineer's Guide to Solar Energy, Solar Energy Information Services, 1979.

(9) Carrier Corp., Handbook of System Design, McGraw-Hill Book Co., N.Y., 1965.

(10) Montgomery, Richard H., with Jim Budnick, The Solar Decision Book, John Wiley & Sons, 1978.

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(12) Anderson, Bruce, Solar Energy Fundamentals in Building Design, McGraw-Hill, 1977.

MODULE: BASIC SOLAR SYSTEMS

UNIT TITLES:

(1) Systems - General

(2) Basic System Configurations

(3) System Related Hardware - Overview

(4) Basic Control Logic

VOCABULARY:

Heat Transfer Fluid
Controls
Direct System
Plastic "pillow" DHW
"Bread Box" DHW
Butch
Thermosyphon
Direct with Recirculation
Direct - drain back
Direct - drain down
Heat Exchanger

System
Liquid System
Air System
Direct Gain
Indirect Gain
Hybrid
Pool System
One Tank
Two Tank
Closed-Loop
Open-Loop

Reference 11, 5
4, 4

Unit 1. Systems General
- A. Define
- B. From collectors to storage
  - 1. Combined storage/collector
  - 2. Air
  - 3. Liquid
    - a. Direct
    - b. Indirect (heat exchanger)
  - 4. Combination air/liquid
- C. From storage to load
  - 1. Combined
  - 2. Air
  - 3. Liquid
    - a. Direct
    - b. Indirect (heat-exchanger)
- D. From collectors to load (without storage)

References 10, 5
12, 5
3, 1
Graphics (Appendix)
SM-2 thru SM10A
PA-1

Unit 2. Basic System Configurations (Graphics Attached)
- A. Direct - define
  - 1. Batch
  - 2. Plastic pillow
  - 3. "Bread box"
  - 4. Thermosyphon
  - 5. Forced circulation
  - 6. Drain back
  - 7. Drain down
- B. Indirect - define
  - 1. Liquid/liquid heat exchanger
    - a. In storage
    - b. Separate from storage
  - 2. Air/liquid heat exchanger
- C. Storage
  - 1. Single tank
  - 2. Multi tank

Reference 1

Unit 3. System Related Hardware - Overview
- A. Liquid systems
  - 1. Open-loop (components, schematic symbols)
  - 2. Closed-loop (components, schematic symbols)
- B. Air systems (components, schematic symbols)

Unit 4. Basic Control Logic
- A. Differential temperature control
- B. Freeze protection

Reference 8, 6
7, 11

Unit 5. Example System Applications (Brief)
- A. DHW
- B. Swimming pool/spa
- C. Space heat
- D. Cooling
- E. Commercial/industrial

Reference 10, 15

Unit 6. Auxiliary System Back-up (Description)
- A. Conventional heating equipment
- B. Conventional cooling equipment
- C. Wood burning stove

STUDENT ACTIVITY

Assignment:

Exercise

Students should, on a test, define solar system, and will list and discuss available options for moving heat from collectors to storage and from storage to load.

As a take-home assignment, students should sketch basic system configurations including the necessary hydronic hardware (using schematic symbols).

On a test, students should explain basic solar control logic including differential control functions and methods of freeze control.

LAB EXERCISE I:

Students should build working models of the basic systems.

Lab Equipment:

Collector(s) (small models)
A variety of hydronic components with hose fittings
Variety of lengths of hose
Mounting board
Control Hardware

Lab Procedure:

Students should build from memory basic systems, fill each system with water, and demonstrate to the instructor that the system works.

MODULE: HYDRONIC SYSTEM COMPONENTS

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Identify hydronic system components.

(2) Describe the purpose and function of these components.

(3) Disassemble, inspect for damage and corrosion, and correctly reassemble hydronic system components.

(4) Write a technical report of the condition of the items inspected in Objective 3.

REFERENCES:

(1) Active Solar Energy System, Design Practice Manual, U.S. Dept. of Energy, Solar/0802-79/01, 1979.

(2) Solar Heating and Cooling of Residential Buildings, Design of Systems, Colorado State University, U.S. Dept. of Commerce, 1977.

(3) Handbook of Fundamentals, ASHRAE, N.Y., 1976.

(4) Handbook of Air Conditioning System Design, McGraw-Hill Book Company, N.Y., 1965.

(5) Fundamentals of Solar Heating, U.S. Dept. of Energy, EG-77-C-01-4038, 1978.

VOCABULARY:

Air Separator

Expansion Tank

Centrifugal Pump

Rotary Pump

Tempering (Mixing) Valve

Pressure Relief Valve

Balancing Valve

Check Valve

Gate Valve

Globe Valve

Three-way Valve

Air Vent

Test Plug (Gauge Adapter)

Heat Exchanger

Vacuum Breaker

Pressure Regulator

Dielectric Union

Anti-Syphon

Reference 3 and 4

Graphics (Appendix)
  PC-2-A
  PC-3-A

Unit 1. Transport Components

- A. Pumps (Review)
  - 1. Centrifugal
    - a. Magnetic coupled
    - b. Direct coupled
  - 2. Rotary
- B. Piping (Review)
  - 1. Types
  - 2. Size
  - 3. Friction loss
  - 4. Appropriate applications

Reference 1 thru 5

Graphics (Appendix)
  PC-4 - PC-9

Unit 2. Flow Components

- A. Valves
  - 1. Check valves
  - 2. Gate valves
  - 3. Globe valves
  - 4. Three-way valves
    - a. Manual
    - b. Motorized
  - 5. Balancing valves
- B. Tempering valves

Reference 1 thru 5

Graphics (Appendix)
  PC-11
  PC-12

Unit 3. System Protecting Components

- A. Expansion tank - closed-loop
  - 1. Pressurized diaphragm
  - 2. System pressured vessel - conventional
  - 3. Sight glass
  - 4. Maintenance
- B. Air eliminators
  - 1. Air separator
  - 2. Air vents
    - a. Air-lock symptoms
    - b. Purging the air from the system
    - c. Automatic air vents
    - d. Manual air vents
- C. Vacuum breakers
- D. Anti-syphon devices
- E. Expansion compensator filters
- F. Flow switch

Reference 1, 2, 3 and 5

Unit 4. System Pressure Components

- A. Pressure regulator
  - 1. Types
  - 2. Pressure setting
- B. Pressure relief valves
  - 1. Pressure only
  - 2. Pressure - temperature
  - 3. Rating (U.L.)
  - 4. Maintenance

C. Pressure test plugs
(gauge adapters)

STUDENT ACTIVITY	Assignment:
Exercise I	Describe, in writing, the purpose and function of: (1) Check valves (2) Pressure-relief valves (3) Tempering valves (4) Vacuum breaker (5) Expansion tank (6) Air separators and air vents.
Exercise II	Draw a schematic diagram of a solar space heating and Domestic hot water system without designation of the hydronic system components.
Procedure:	The student should identify, on the drawing, each hydronic system component, place a number beside it, and describe the purpose and function of each and how it relates to the total system.
LAB EXERCISE I: Lab Equipment:	Hand Tools, Check Valve, Gate Valve, Motorized Zone Valve, Pressure Regulator.
Lab Procedure:	The student should disassemble each of the above devices, inspect for damage or corrosion, write a technical report on the condition of each, and reassemble each device.

MODULE: HEAT TRANSFER FLUIDS

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Identify the common heat transfer fluid options and their characteristics.

(2) Solve problems relating to general fluid design associated with heat transfer fluids.

REFERENCES:

(1) Montgomery, Richard H., with Jim Budnick, The Solar Decision Book, John Wiley & Sons, 1978.

(2) Cole, Roger L., et al, Design & Installation Manual for Thermal Energy Storage, U.S. Dept. of Energy, 1980, ANL-79-15.

(3) Franklin Research Center, Installation Guidelines for Solar DHW Systems in One- and Two-Family Dwellings, U.S. Dept. of Housing and Urban Development, 1980.

UNIT TITLES:

(1) Heat Transfer Fluids and General Characteristics

(2) Fluid Design Considerations

VOCABULARY:

Heat Transfer Fluid

Petroleum (Mineral) Oils

Darcy-Weibach Equation

Reynolds Number

Ethylene Glycol

Propylene Glycol

Specific Heat

Fluid

Silicone Fluids

Air

Water

Fluid Velocity

Pressure Drop

Heat Capacity

References 3
2, B

Unit 1. Heat Transfer Fluids and General Characteristics

- A. Air
    1. Cost
    2. Temperature limits
    3. Leaks in ducting
    4. Blower power (Fan Laws)
    5. Heat capacity
- B. Water
    1. Cost
    2. Temperature limits
    3. Corrosion
    4. Heat capacity
    5. Thermal conductivity
    6. Viscosity
- C. Ethylene glycol
    1. Cost
    2. Temperature range
    3. Corrosion inhibitors
    4. Thermal properties
    5. Oxidation
    6. Toxicity
    7. Flash point
    8. Boiling point
- D. Propylene glycol
    1. Cost
    2. Temperature range
    3. Corrosion inhibitors
    4. Thermal properties
    5. Oxidation
    6. Toxicity
    7. Flash point
    8. Boiling point
- E. Other glycols
    1. Diethylene glycol
    2. Triethylene glycol
    3. Polyalkylene glycol
- F. Petroleum (mineral) oils
    1. Cost
    2. Temperature range
    3. Thermal properties
    4. Flash point
    5. Boiling point
    6. High temperature oxidation and by-products

Reference 1, 11

G. Silicone Fluids
  1. Cost
  2. Temperature range
  3. Thermal properties
  4. Stability
  5. Vapor pressure
  6. Surface tension

H. Other fluids

Reference 2, B

Unit 2. Fluid Design Considerations
  A. Darcy-Weibach Equation (pressure drop in tube)
  B. Reynold's Number
  C. Fluid velocity
  D. Pressure drop
    1. Tubing
    2. Fittings
    3. Heat exchangers

STUDENT ACTIVITY

Assignment:

Exercises:

On a test, student should define heat transfer fluids and identify the common heat transfer options and their characteristics.

Student should solve problems to determine pressure drop through tubes and heat exchangers (shell-and-tube, tube-in-tube).

Student should, on a test, identify the heat transfer fluid options and their characteristics.

LAB EXERCISE I:

Students should determine heat capacity of fluids.

Lab Equipment:

Variety of heat transfer fluids
Calorimeter cups
Boiling water
Large steel balls of equal mass

Lab Procedure:

(1) Allow all steel balls to come to thermal equilibrium in the boiling water.

(2) With a different heat transfer fluid (at room temperature) in each calorimeter cup, drop one steel ball in each cup.

(3) Measure temperature and determine the heat capacity of each fluid.

LAB EXERCISE II: Students should determine heat capacity of a glycol solution as a function of the water/glycol solution ratio.

Lab Equipment:

Ethylene glycol
Calorimeter cups
Immersion heater
Watt meter
Water

Lab Procedure:

(1) Mix in separate calorimeter cups solutions of 10058 water, 10058 glycol, and water/glycol in proportions of 25/75, 50/50, and 75/25.

(2) In each of the five solutions, monitor temperature rise and electric power usage.

(3) Determine heat capacity of each fluid and compare to accepted standards. Plot and analyze.

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Discuss the function of heat exchangers.

(2) Classify heat exchangers.

(3) Analyze efficiency penalties due to using heat exchangers in solar systems.

(4) Write a general specification for a heat exchanger.

(5) Calculate necessary flow rates using the matched capacity rate concept.

REFERENCES:

(1) Cole, Roger L., et al, Design & Installation Manual for Thermal Energy Storage, U.S. Dept. of Energy, 1980, ANL-79-15.

(2) Horel, John D., Francis deWinter, Investigation of Methods of Heat Transfer from Solar Liquid Heating Collectors to Heat Storage Tanks, U.S. Dept. of Energy, SAN-1238-1.

(3) Montgomery, Richard H., with Jim Budnick, The Solar Decision Book, John Wiley & Sons, 1978.

(4) Howell, Yvonne, and Justin A. Bereny, Engineer's Guide to Solar Energy, Solar Energy Information Services, 1979.

(5) Kreith, Frank, and Jan F. Kreider, Principals of Solar Engineering, McGraw-Hill, 1978.

(6) Solar Heating Systems Manual, ITT Training & Education Dept., Fluid Handling Division, 1977.

UNIT TITLES:

(1) Introduction

(2) Classification

(3) General Specification Criteria

(4) General Sizing Criteria

VOCABULARY:

U-tube Bundle

Traced Tank

Parallel Flow

Parallel-Counterflow

Direct Contact

Double Wall

Approach Temperature

Tube-in-tube

Spiral Tube

Shell-and-Tube

Counter Flow

Cross Flow

Finned Tube

Single Wall

Wrap Around Shell

Tank-in-tank

Bore Tube

Unit 1. Introduction
- A. Definition
- B. Purpose of heat exchangers in solar systems

Reference 2, 2, 3
1, D
These references have several excellent graphics

Unit 2. Classification
- A. Separate from storage
  - 1. Shell-and-tube
    - a. Counter flow
    - b. Parallel flow
    - c. Cross flow
    - d. Parallel-counter flow
    - e. Bore tube
    - f. Finned tube
    - g. Spiral tube
  - 2. Tube-in-tube
    - a. Counter flow
    - b. Parallel flow
  - 3. Finned tube
- B. Integrated with storage
  - 1. In-tank heater
    - a. U-tube bundle
    - b. Coil
    - c. Tank in tank
  - 2. Tank wall heater
    - a. Traced tank
    - b. Wrap-around shell
  - 3. Rock-bed
  - 4. Direct contact
  - 5. Thermal mass (passive architecture)

Reference 1
This could be partially a handout

Unit 3. General Specification Criteria
- A. Efficiency penalties
- B. Economics of size
- C. Materials and/or work included
- D. Related materials or work
- E. Details
- F. Codes and standards
- G. Construction
- H. Accessories (optional)
- I. Capacity and dimensional requirements
- J. Drawings
- K. Manufacturers specifications

Reference 6, 4

Unit 4. General Sizing Criteria
- A. Heat exchange fluids
- B. Approach temperature difference
- C. Flow rates and matched capacity

STUDENT ACTIVITY

Exercises

Assignment:

(1) Students will write a definition of heat exchanger and discuss their purpose.

(2) Students will identify the classifications of heat exchangers on a test.

(3) Students will describe efficiency penalties and determine the correct heat exchanger size and flow rates for a given solar system.

(4) Students will write a general or specific specification for the heat exchanger in (3) above.

LAB EXERCISE I:

Compare performance of two systems identical except for heat exchangers.

Lab Equipment:

Two identical water storage tanks with different sized U-tube bundle heaters
Temperature monitoring equipment
Collectors and other system components as necessary to collect heat
Flow measuring device

Lab Procedure:

(1) Divert heated transfer fluid through one U-tube bundle while monitoring flow rate, temperature in and temperature out of the bundle, and temperature of the storage tank.

(2) After recording a sufficient amount of data, divert the heated transfer fluid to the other U-tube bundle. Maintain the same flow rate. Monitor temperatures in and out of the heat exchanger and in the tank.

(3) Contrast and compare data to analyze relative performances.

MODULE: AIR DISTRIBUTION COMPONENTS

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Compare and contrast fan types.

(2) Identify and describe the function of ducts and duct fittings.

(3) Measure cubic feet/minute of air delivered by the system.

(4) (Optional) Calculate system efficiency.

REFERENCES:

(1) *Handbook of Fundamentals*, ASHRAE, N.Y., 1976.

(2) *Trane's Air Conditioning Manual*. The Trane Co., LaCrosse, Wisconsin, 1974.

(3) *Air Distribution System Design*, *Manual D*, NESCA, Arlington, Virginia, 1979.

(4) *Solar Heating and Cooling in Residential Buildings*, *Design of Systems*, Colorado State University, U.S. Dept. of Commerce, 1977.

VOCABULARY:

Fan Laws

Duct

Blower

Centrifugal

Propeller

Fan

Elbows

Tees

Sound Level - Decibels

External Static Pressure

Static Pressure

Aspect Ratio

Branch Trunk

Register

Supply Air

Return Air

Pressure Drop

Manometer

C.F.M.

Friction Loss

Velocity

Turbulence

Turning Vanes

Dampers

Transition Piece

Plenum

Main Trunk

Return Grille

Filter

Room Load

Reference 1, and 2

Unit 1. Fans and Fan Laws

- A. Centrifugal fans
  - 1. Types
  - 2. Performance
  - 3. Horsepower requirements
  - 4. Efficiency
- B. Axial (Propeller) fans
  - 1. Types
  - 2. Performance
  - 3. Horsepower requirements
  - 4. Efficiency
- C. Fan laws
  - 1. Air volume
  - 2. Static pressure
  - 3. Velocity or total pressure
  - 4. Air density
  - 5. Variable speeds (effects)
  - 6. Example problems

Reference 1, 2 and 3

Unit 2. Ducts

- A. Types
  - 1. Round
  - 2. Square or rectangular
- B. Insulation
- C. Sound level
  - 1. Velocity
  - 2. Damping effect
  - 3. Vibrations
  - 4. Testing methods
  - 5. Acceptable decibel levels
- D. Friction loss
- E. Main trunk
- F. Branch trunk
- G. Supply air duct
- H. Return air duct

Unit 3. Duct and Plenum Fittings

- A. Elbow
  - 1. Short radius
  - 2. Long radius
  - 3. Turning vanes
  - 4. Degree of bend
    - a. 30°
    - b. 45°
  - 5. Aspect ratio
    - a. 60°
    - b. 90°
- B. Tees
- C. Y fittings
- D. Reducers
- E. Turbulence

F. Pressure drop
G. Transition piece
H. Dampers
I. Plenum configurations

Unit 4. Air Measurement (Briefly)
  A. C.F.M. (cubic feet/minute)
  B. External static pressure and velocity pressure
  C. Room delivery
    1. Supply registers
    2. Return grilles
  D. Manometers
  E. Velometers

STUDENT ACTIVITY

Assignment:

Exercise

Given a group of air distribution system components (suggest a graphic representation) the student will identify the components and describe their function.

LAB EXERCISE I:

A Solar Air System (Heating) with numbers on the various components.

Lab Procedure:

The student will list, by number, the components of the air distribution system. The student will also describe the function of each component.

LAB EXERCISE II:

Lab Equipment:

An operational air distribution system
Velometer
Flexible tape measure
Inclined manometer

Lab Procedure:

(1) The student will determine the C.F.M. delivered at each supply register.

(2) Total the C.F.M. delivered by all supply registers.

(3) Determine the C.F.M. delivered by the fan at the plenum.

(4) (Optional) Calculate the system ducts losses and efficiency by comparing fan capability with delivery.

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Identify controllers, sensors, and controlled devices common to solar systems.

(2) Describe the function and applicable theory for solar system controllers.

(3) Analyze and describe the sequence of operation for solar control systems.

REFERENCES:

(1) Haines, Roger W., *Control Systems for Heating, Ventilation and Air Conditioning* Van Nostrand Reinhold, Environmental Engineering Series, N.Y., 1971.

(2) *Fundamentals of Solar Heating*, U.S. Dept. of Energy, EG-77-C-01-4038, Washington, D.C., 1978.

(3) *Carrier's Handbook of System Design*, McGraw-Hill Book Co., N.Y., 1965.

(4) Haines, John E., *Automatic Control of Heating and Air Conditioning*, McGraw-Hill Book Co., N.Y., 1961.

VOCABULARY:

Multi-stage Thermostat

Differential Controller

Bimetal Sensor

Bellow/diaphragm Sensors

Pressure Controls

Thermostat

Pneumatic Controls

Pressure Relief Valve

Mechanical Controls

Damper

Motorized Damper

Control Device

Controller

Controlled

Aquastat

Sensing Wells

Zone Valves

Relays

Electric Controls

Reset

Limit Switch

Photoelectric Cells

Sensors

Thermocouple

Thermopile

Thermistors

Magnetic Reed Switch

Timers

Solenoids

Contactors

Mixing Valves

Single Stage

Reference 1, 4

Unit 1. Control Theory
- A. Define
  - 1. Control - controller
  - 2. Controlled
  - 3. Sensors
- B. Purpose of control
  - 1. Measurement to power - set points to action
  - 2. Control variables
- C. Control action
  - 1. On-Off
  - 2. Timed
  - 3. Floating
  - 4. Proportional
  - 5. Differential
  - 6. Actuator
  - 7. Limiters
- D. Energy sources
  - 1. Electric
  - 2. Electronic
  - 3. Pneumatic
  - 4. Hydraulic
  - 5. Fluidic
  - 6. Self-contained
  - 7. Amplifiers
  - 8. Circulation circuit
    - a. Valves
    - b. Dampers
    - c. Diverters

Unit 2. Control Systems - Basic
- A. Controlled devices
  - 1. Collectors
  - 2. Pumps
  - 3. Storage
  - 4. Auxiliary system
  - 5. Purge coil
  - 6. Shutters
  - 7. Insulation blankets, walls, panels

- B. Sensors
  - 1. Aquastat
  - 2. Pressurestat
  - 3. Pressure control
    - a. High
    - b. Low
  - 4. Thermocouples
  - 5. Thermopiles
  - 6. Thermistors
  - 7. Bimetal

8. Thermostat
    a. Single stage
    b. Multi-stage
    c. Differential
9. Photoelectric cells
10. Timers
11. Magnetic reed switches

C. Controllers
    1. Zone valves
    2. Solenoids
    3. Dampers
    4. Relays and switches
    5. Contactors
    6. Three-way valves
    7. Pressure-relief valve
    8. Return air limiters
    9. Motors
    10. Reversing valves
    11. Auxiliary heating components
    12. Auxiliary cooling components

Unit 3. Basic Control Systems
- A. Air controls - fresh
- B. Humidity control
- C. Temperature control
    1. Heating
    2. Cooling
- D. Domestic hot water
- E. System interlocks
- F. Monitoring
    1. Sun-tracking
    2. Flow
        a. Air
        b. Liquid
- G. Pressure controls
    1. Actuating devices
    2. Safety devices

STUDENT ACTIVITY

Exercise

Assignment:

Outside Classroom

(1) Explain, in written narrative form, the function of controllers, sensors, and their relationship to the controlled device.

(2) Given a schematic diagram of a solar domestic hot water system, the student should:

a. Identify and list the sensors
b. Identify and list the controllers
c. Identify and list the controlled devices including which controllers control them.

LAB EXERCISE I:

Lab Equipment:

Single stage thermostat
Multi-stage thermostat
Aquastat
Pressurestat
Differential thermostat
Relays
Contactors
Pressure relief valve
Three-way valve
Timing device
Photoelectric cell
Thermocouple
Solenoid valve

(Each of the above should be numbered with no other identification.)

Lab Procedure:

The student should identify by name and function each of the numbered controllers and controlled devices.

LAB EXERCISE II:

Lab Equipment:	Schematic diagram of a small residential solar heating and hot water system, including controls and controlled devices.
Lab Procedure:	The student should describe the sequence of operation for the system in the:

(1) Space heating
  a. Collector to space heating mode
  b. Collector to storage mode
  c. Auxiliary space heating mode.

(2) Domestic hot water (DHW)
  a. Collector to storage or pre-heat
  b. Auxiliary DHW mode.

MODULE: BASIC SYSTEM SIZING

OBJECTIVE:

Upon completion of this module, the student should be able to:

(1) Calculate a DHW load.

(2) Determine total useful energy gain (Btu/ft^2-day) on a monthly basis.

(3) Estimate the yearly solar fraction.

REFERENCES:

(1) *Copper Brass Bronze Design Handbook: Solar Energy Systems*, Copper Development Association, Inc.

(2) *Solar Heating Systems Design Manual*, ITT Training and Education Dept., Fluid Handling Division, 1977.

(3) Beckman, William A., *et al*, *Solar Heating Design by the f-Chart Method*, John Wiley & Sons, 1977.

(4) Solar Energy Applications Laboratory, Colorado State University, *Solar Heating and Cooling of Residential Buildings - Sizing Installation and Operation of Systems*, U.S. Dept. of Commerce, 1977, Stock No. 003-011-00085-2.

UNIT TITLES:

(1) Design Constraints

(2) The Load

(3) Collector Output

(4) Sizing the Array

(5) Storage Rules of Thumb

(6) The System

VOCABULARY:

Source Water Temperature

DHW

Degree Day

Annual Percentage Solar

Load

Space Heat

Collector Efficiency

MODULE: BASIC SYSTEM SIZING

NOTE: This is based on Reference 4; however, the principles are widely applied by other solar sizing methods. (Examples of other methods).

Unit 1. Design Constraints and Assumptions

Reference 1, 7, A, B, C

Graphic (Appendix) SM-1

Unit 2. The Load
- A. Define
- B. Monthly calculation requirements
- C. DHW
  - 1. Source water temperature
  - 2. Use patterns
  - 3. Temperature needed in storage
- D. Annual load demand
- E. Space heat (brief)
- F. Graphical representation

Unit 3. Collector Output
- A. Collector efficiency curve
- B. Ambient temperature
- C. Collector fluid temperature
- D. Insolation available
- E. Collector tilt
- F. Daily, monthly, and/or annual output per unit area

Unit 4. Sizing the Array
- A. March output vs. load
- B. Trial calculations
- C. Annual solar fraction

Unit 5. Storage Rules of Thumb
- A. Air systems
- B. Liquid systems

Reference 1, 6

Unit 6. Subsystem Component Selection
- A. Fluid flow rate
- B. Pump/fan and pipe/duct sizing
- C. Control method and devices
- D. Specifications

STUDENT ACTIVITY

Assignment:

Exercise

Student should use the Copper Development Association Inc. solar design method (or comparable method) to:

(1) Determine DHW load.

(2) Determine total useful energy gain on a monthly basis.

(3) Determine yearly solar fraction.

LAB EXERCISE I:

Given a DHW load, students should determine the solar component sizes, make a line drawing of the system, and write specifications for the components.

EXPERIMENT: SOLAR POSITION AND TIME

Purpose:

In solar energy applications, it is important for the technician to know and understand the path which the sun takes across the sky on both a daily and seasonal basis. The position of the sun can be designated by date, solar time, altitude, and azimuth.

The date is the calendar date. Solar time is recorded similar to clock time except that solar time always has solar noon when the sun is highest in the sky (i.e., halfway between sunrise and sunset). One hour before solar noon would be 11:00 solar time. Three hours before solar noon would be 9:00 solar time, etc.

Altitude is a measure of how high the sun is above the horizon. Imagine pointing with one arm at the sun and with the other at the horizon directly below the sun. The angle in degrees with your arms would give the altitude.

The azimuth is the angular measurement of the sun's position away from true south. (Note: Magnetic south and true south are usually not the same. The difference varies from location to location). If you point one arm at the horizon directly below the sun and point the other arm at true south, the angle in degrees between your arms is the azimuth. The value of the azimuth is normally designated as so many degrees east or west depending upon whether it is morning or afternoon. (Some references designate true North as 0°, East as 90°, South as 180°, and West as 270°.)

This experiment is designed to acquaint the solar energy student with solar position, solar time, and true south.

Equipment:

The following equipment will be needed to gather and analyze the data.

(1) Shadow Board/with shadow pole (DWG. No. L-3, SH-1)

(2) Level

(3) Shadow-data recording data (DWG. No. L-3, SH-2)

(4) Altitude and Azimuth graph paper (DWG. No. L-3, SH-3)

(5) Magnetic Compass

(6) Clear sky all day.

Procedure:

(1) Locate a level area which will not be shaded all day.

(2) Punch the indicated hole in the shadow tracing paper just south of the origin and use masking tape to mount on the shadow board with the hole in the board and the paper lined up.

(3) Align the board such that the side closest to the shadow pole hole (long side) faces south. Use a compass to place the short sides in a north-south alignment. This will align the board and shadow data recording paper according to magnetic north.

(4) Use a bubble level to insure that the board is level in both the north-south direction and the east-west direction.

(5) Insure the shadow pole and measure to be sure that the height above the board is exactly 5.7 cm (2.25 in).

(6) Beginning in the early morning, very carefully mark the position of the tip of the shadow and note the time of the mark on the data recording paper. Mark the position and record the time at regular intervals throughout the day until sunset. These intervals should be short enough to insure a smooth and accurate curve on the final graph. During the time period during which the shadow from the pole is shortest (approaching solar noon) record data at even closer intervals. NOTE: Be absolutely certain that the assembly is not moved during the entire data gather period (i.e., all day).

(7) After recording a full day of data, remove the pole. Write the date of the data on the recording paper. Use a smooth curve to connect all the data points on the page.

(8) Determine true south by finding the point on the curve which represents the shortest shadow cast by the pole during the day-long movement. Carefully draw a straight line through that point on the curve and the origin of the recording paper. How does this line compare to the short edge of the shadow board which you lined up with magnetic south? How many degrees different is the solar south line?

(9) The point on the curve corresponding to the shortest shadow length also represents solar noon. What is the equivalent clock time? Does it change with latitude? Longitude? Daylight saving time?

(10) Using a protractor and measuring from solar south (determined in step 7), transcribe the data onto the altitude and azimuth graph paper. Please note that altitude can be read from the concentric rings and azimuth must be determined using a protractor.

NOTE: Data recorded on the west side of the shadow-data recording paper represents sun position in the east sky.

(11) Wait 3-4 weeks and repeat the experiment. This time attempt to line the board with true south using a magnetic compass and the information gained in Step 8. Wait 3-4 more weeks and repeat the experiment again aligning with true south. Transcribe all experimental data to the same graph paper. Be sure to keep records in your lab book.

How does the altitude and azimuth change seasonally? Use dashed lines to indicate a probable path for the sun on the longest day of the summer.

Error Analysis:

Name several possible sources of error and the probably effect on the results.

After recording three sets of data at 3-4 week intervals, consolidate all data and turn in as a formal write-up.

COLLECTORS AND ENERGY STORAGE

Representative
Pre-Tests
and
Post-Tests

COURSE PRE-TEST

Make the best choice

1. Energy is often defined as:
   a. work per unit time
   b. a capacity to do work
   c. power
   d. none of the above

2. A flat plate collector:
   a. utilizes diffuse light only
   b. utilizes direct beam light only
   c. utilizes both beam and diffuse light
   d. none of the above

3. Which of the following waves is not a part of the electromagnetic spectrum:
   a. ultraviolet
   b. sound
   c. visible
   d. infrared
   e. radio

4. Convection currents in matter are produced by:
   a. high density fluids
   b. low density fluids
   c. constant temperature conditions throughout a fluid
   d. warmer temperature conditions existing on the lower surfaces of a container containing a fluid than exists at the top of the container

5. Converting sugar to ethyl alcohol is commonly accomplished by:
   a. biological conversion
   b. thermal conversion
   c. photovoltaic conversion
   d. none of the above

6. Flat plate fluid flow is not represented by which of the expressions below:
   a. header flow
   b. serpentine flow
   c. spiral flow
   d. natural convectional flow

7. Solar insolation rate depends on all but which one of the following expressions:
   a. air capacity
   b. air mass
   c. time of day
   d. time of year
   e. atmospheric temperature

8. A black pipe swimming pool solar collector is classified as:
   a. a low temperature collector
   b. an intermediate temperature collector
   c. a high temperature collector
   d. none of the above

9. Active solar systems utilize which one of the following key expressions:
   a. a pump or blower
   b. natural circulation of fluid
   c. sensible heat storage
   d. latent heat storage

10. Which one of the following terms is not helpful in expressing the location of the sun:
    a. solar altitude
    b. solar azimuth
    c. solar constant
    d. solar zenith angle

11. Most concentrating collectors:
    a. use tracking mechanisms
    b. utilize diffuse sunlight
    c. are cheaper than flat plate collectors
    d. have lower efficiency than flat plate collectors at higher temperature

12. Solar altitude is highest at solar noon on:
    a. spring equinox
    b. autumnal equinox
    c. winter solstice
    d. summer solstice

13. A solar pyranometer measures:
    a. solar temperatures
    b. solar insolation rate
    c. thermal conductivity
    d. none of the above

14. The radiation rate of a body is not determined by which one of the expressions listed below:
    a. temperature of the body
    b. emissivity of its surface
    c. volume of the body
    d. area of the body

15. Thermal transfer by convection is:
    a. moving energy by moving mass containing the energy
    b. is never efficient
    c. is used in thermal transfer from the sun surface to the earth
    d. none of the above

16. Thermal conductivity is not determined by which one of the following expressions:
    a. area of the surfaces
    b. K-value of the medium between the surfaces
    c. ΔT between the surfaces
    d. distance between the surfaces
    e. color of the transmitting medium

17. Water has a high:
    a. thermal conductivity
    b. specific heat
    c. viscosity
    d. instability
    compared to most other substances.

18. When fluids are in motion, static pressure is equal to:
    a. total pressure minus velocity pressure
    b. total pressure plus velocity pressure
    c. none of the above

19. When a piping system is carrying moving water the friction head losses are not determined by which one of the following expressions:
    a. length of the pipe
    b. diameter of the pipe
    c. smoothness of the inside pipe surface
    d. vertical height of the pipe
    e. speed of water in the pipe

20. The capacity of water flow through a pipe can be calculated by which of the following expressions below: (ft^3 / min)
    a. speed times time
    b. pipe cross section area times speed of water flow
    c. $4 \pi R^2$ x water speed
    d. $4/3 \pi R^3$ x water speed

21. The pressure needed to pump water 60 ft vertically is: (lb/in^2)
    a. (.43 x 60) lb/in^2
    b. (4.3 x 60) lb/in^2
    c. 60 lb/in^2
    d. none of the above

22. Pipe fittings in a piping system always contribute to:
    a. a decrease in friction head
    b. an increase in flow rate
    c. turbulent flow
    d. an increase in flow speed
    e. none of the above

23. In order to determine the flow capacity of a duct system, which one of the following expressions are not needed:
    a. diameter of the duct
    b. static pressure
    c. average velocity pressure across the cross-section of the duct
    d. temperature of the air

24. The maximum speed water should be made to flow through a pipe is:
    a. less than 4 ft/sec
    b. near 7 ft/sec
    c. near 12 ft/sec
    d. near 16 ft/sec

25. A good flat plate collector glazing should not have which one of the following properties:
    a. should selectively transmit thermal infrared waves well
    b. should be transparent to visible rays
    c. should be transparent to near infrared waves
    d. should have good durability and good thermal insulating properties

26. A good flat plate absorber plate should not have which one of the following properties:
    a. should have high absorptivity
    b. should have a small conductivity constant
    c. should have a low emissivity in its working temperature range
    d. should have a good thermal bond to the circulating fluid line

27. A good flat plate collector should not have which of the following properties:
    a. risers connecting the headers should be 4 inches apart or closer
    b. good durability properties at high temperature
    c. should have high air infiltration rates
    d. should have a good thermally insulated box
    e. should be aesthetically pleasing

28. Flat plate stagnant temperature needs to be considered for:
    a. glazing and insulation choices to prevent out gassing
    b. circulatine flow rate
    c. collector tilt to use
    d. header verses serpentine options

29. The water circulation flow rate through a flat plate collector is 2 gal/min. An inlet temperature of 110 degrees (F) and a outlet temperature of 125 degrees (f) is operating at good insolation conditions. The thermal energy given to the transport system by the collector is:
    a. 125 BTU/min
    b. 250 BTU/min
    c. 500 BTU/min
    d. 1,000 BTU/min

30. The absorber plate used in a concentrating collector is not which one of the following expressions:
    a. is smaller than the aperture area of the collector
    b. is often selectively coated
    c. is sometimes evacuated of surrounding air
    d. is a good thermal insulator
    e. is not subject to chemical degradation

31. Dish concentrating collectors often:
    a. have concentration ratios less than one
    b. have sharp focus
    c. produce extremely high temperature
    d. do not need tracking
    e. may be parabolic or spherical

List first correct response only

32. Rock storage utilizes which type of the following storage mechanisms:
    a. phase change
    b. chemical storage
    c. sensible heat storage
    d. none of the above

33. A notable advantage of phase change storage in solar space heating is:
    a. low cost of storage medium
    b. large thermal capacity per unit volume of space utilized at working temperature needed
    c. simple design features
    d. phase change salts are basically non-corrosive

34. Thermal storage considerations that are important are listed below. Which one is least important?
    a. thermal capacity
    b. cost of storage
    c. durability of the storage system
    d. size and location of storage system
    e. aesthetics of the storage system

35. Slab thermal storage may be practical in some areas of the country for:
    a. D H W storage
    b. space heating
    c. industrial heat
    d. none of the above

36. A notable advantage of a closed loop drain-back DHW system might be:
    a. needs a high head pump
    b. requires a heat exchanger
    c. near absolute control of freeze protection and very little mineralization of the collector absorber tubes
    d. none of the above

37. A thermistor has its electrical resistance:
    a. increase with an increase in temperature
    b. decrease with an increase in temperature
    c. remain constant with an increase in temperature

38. In a DHW system the check valve serves to:
    a. help in freeze control
    b. prevent reverse thermosiphoning
    c. neither of the above

39. A dual loop DHW system utilizes:
    a. a single circulating pump
    b. an external heat exchanger
    c. a double differential control system
    d. none of the above

40. A direct recirculation freeze protection system is practical in:
    a. Denver, Colorado
    b. Atlanta, Georgia
    c. Pittsburgh, Pennsylvania
    d. Ft. Myers, Florida
    e. none of the above

41. A passive hydronic DHW system requires:
    a. special freeze protection mechanism
    b. tank be a few feet lower than the top of the collector
    c. that the circulation lines be smaller than an active comparable system
    d. that the tank be distant from the collector

42. Pressure - temperature relief valves are often utilized in a DHW system:
    a. on the tank and collector
    b. on the expansion tank
    c. near the check valve
    d. near the pump

43. An automatic air valve on DHW systems permits:
    a. elimination of isolation valves
    b. elimination of check valve
    c. elimination of air expansion tank
    d. manual drain down of collector

44. A distinct disadvantage of silicone heat transfer fluids is:
    a. very low freezing temperature
    b. very high boiling temperature
    c. high initial cost
    d. low toxicity and corrosion properties

45. Ethylene glycol when used as a heat transfer fluid: (50-50 ratio)
    a. is non- toxic
    b. does not have to be replaced for the life of the system
    c. will degrade to produce sludge and organic acids at high temperature
    d. has a lower viscosity than pure water

46. Counterflow heat exchangers are:
    a. the most effective
    b. must be external to the tank in application
    c. may not be double wall
    d. none of the above

47. A manometer measures:
    a. temperature differences
    b. pressure differences of fluids
    c. air speed directly
    d. none of the above

48. A thermostat is a temperature selective:
    a. pneumatic switch
    b. electrical switch
    c. pressure switch
    d. monometer

49. A motorized damper is most likely found on:
    a. a hydronic DHW system
    b. a solar air heating system
    c. a pool heating system (solar)
    d. none of the above

50. On a DHW system, the differential controller regulates:
    a. circulating pump action
    b. zone relays
    c. aquastats
    d. mixing valves
    e. none of the above

TEST: COLLECTOR AND ENERGY STORAGE

COURSE PRE-TEST KEY

1. B
2. C
3. B
4. D
5. A
6. C
7. E
8. A
9. A
10. C
11. A
12. D
13. B
14. C
15. A
16. E
17. B
18. A
19. D
20. B
21. A
22. C
23. B
24. B
25. A
26. B
27. C
28. A
29. B
30. D
31. B
32. C
33. B
34. E
35. B
36. C
37. B
38. B
39. B
40. D
41. A
42. A
43. D
44. D
45. C
46. A
47. B
48. B
49. B
50. A

OVERVIEW

POST TEST

I Make the best match (one point each)

____ 1. energy

____ 2. electromagnetic wave

____ 3. flat plate collector

____ 4. concentrating collector

____ 5. thermal storage

____ 6. cost effectiveness

____ 7. photovoltaic conversion

____ 8. thermal conversion

____ 9. biological conversion

____10. active solar

____11. passive solar

____12. OTEC

____13. thermal load

____14. sun

____15. wind energy

A. utilizes beam and diffuse radiation

B. practical at north east end of Great Lakes

C. light to electricity

D. tapping the thermal energy of the ocean

E. uses pumps or blowers

F. electromagnetic radiation to heat

G. simple pay back

H. a nuclear furnace

I. go the speed of light

J. sugar to alcohol

K. capacity to do work

L. natural convection

M. solar availability is intermittent

N. end use of heat energy

O. needed for high temperature performance

TEST: COLLECTOR AND ENERGY STORAGE

II Problem and Diagrams

1. Illustrate by block diagram how energy goes from the sun, to flat plate collector to storage to load for a DHW System.

2. Illustrate by diagram Solar Passive Design as an aid in heating a home.

3. Show by equation the conversion of sucrose to alcohol.

4. Illustrate the size or magnitude comparison of the following pairs of terms.

   A. joules to calories

   B. calories to Btu

   C. Btu to KWH

   D. watts to Hp

   E. ft. lb. / sec. to Hp

5. Show by simple block diagram an ocean thermal energy conversion system.

6. List at least (5) significant reasons why solar energy should be harnessed.

   A.

   B.

   C.

   D.

   E.

7. List the contributions of at least (5) men in history, their contribution to solar energy application, and the approximate date of involvement.

	Men	Contribution	Date
1.			
2.			
3.			
4.			
5.			

OVERVIEW

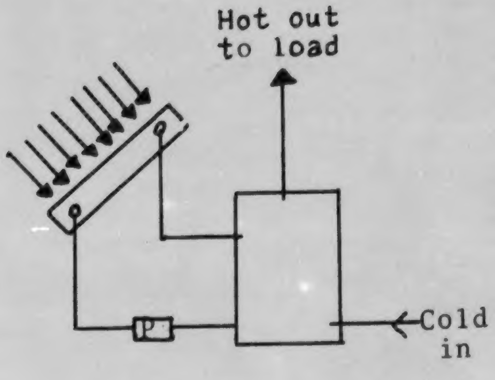
POST-TEST KEY

I Matching

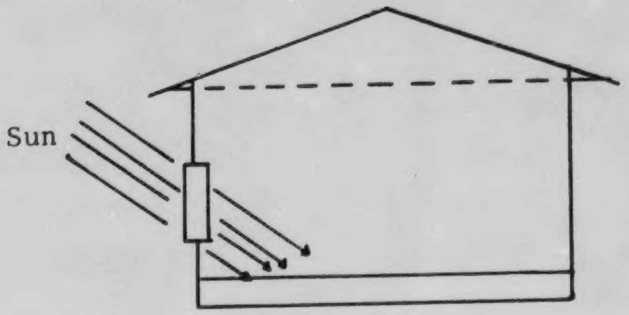
1. K
2. I
3. A
4. O
5. M
6. G
7. C
8. F
9. J
10. E
11. L
12. D
13. N
14. H
15. B

II Problems

1.



2.

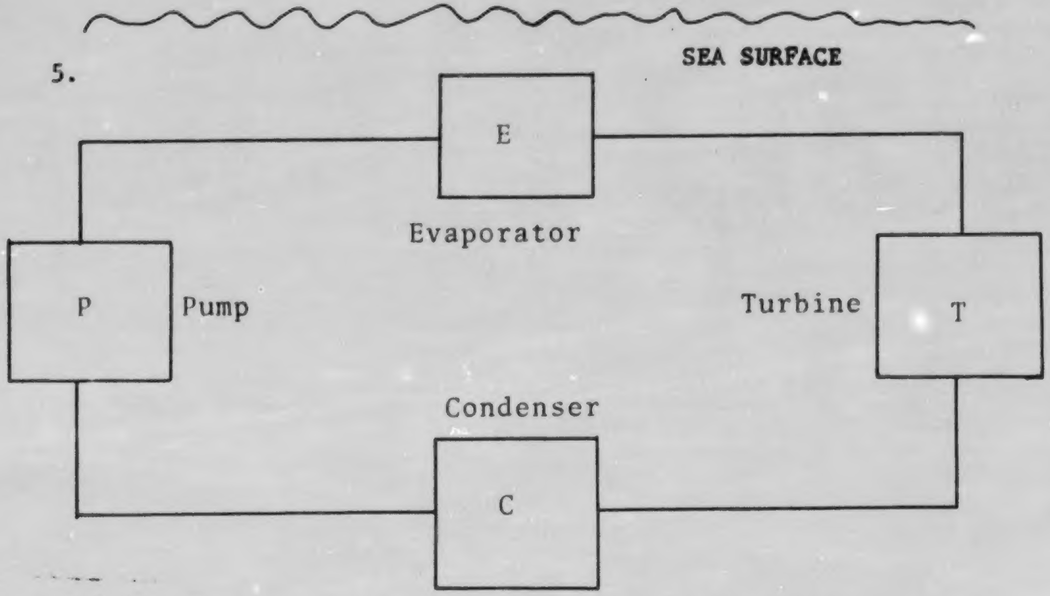


3. $C_{12}H_{22}O_{11} + H_2O \quad 2C_6H_{12}O_6$

$C_6H_{12}O_6$ enzyme $2C_2H_5OH + 2CO_2$

4. A. 4.19 joule = 1 calorie
   B. 252 calories = 1 BTU
   C. 3413 BTU = 1 KWH
   D. 746 watts = 1 Hp
   E. 550 ft lb/sec = 1 Hp

5.



6. A. can be cost effective for some applications
   B. is locally available in predictable amounts
   C. does not appreciately pollute the air or water
   D. saves fossil molecules for non- thermal uses
   E. provides for the national defense

7.*

A.	Lavoisier	High temperature chemical reactions	1772
B.	Trombe	Trombe wall	1970
C.	Eriecsson	Solar steam engine	1868
D.	Schmidt	Selective solar absorber	1960
E.	Boer	Solar cells	1945

* From "Solar Energy" The Awakening Science, Daniel Behrmann Little Brown & Company, 1976.

SOLAR ENERGY CHARACTERISTICS

POST-TEST

I. Make the best choice (one point each)

____ 1. air mass

____ 2. solar constant

____ 3. total radiation

____ 4. thermal infrared

____ 5. near infrared

____ 6. pyranometer

____ 7. pyroheliometer

____ 8. local solar time

____ 9. altitude

____ 10. azimuth

____ 11. zenith

____ 12. insolation rate

____ 13. inverse square law

____ 14. tracking collector

____ 15. ultraviolet

____ 16. visible light

____ 17. solar noon

____ 18. black body

____ 19. summer solstace

____ 20. winter solstace

____ 21. spring equinox

____ 22. autumnal equinox

A. will penetrate collector glazing

B. Sept. 21st

C. rarely matches clock time

D. west equals 90 degrees

E. Dec. 21st

F. beam plus diffuse

G. contains colors of the rainbow

H. should not penetrate collector glazing

I. angle above the horizon

J. follows the sun

K. diminishes solar intensity

L. March 21st

M. over head

N. ideal radiator

O. measures total availability

P. light

Q. 428 BTU/ft^2 hr

R. June 21st

S. energy per unit of time

T. greatest solar altitude

U. destructive to various materials

V. measures solar beam intensity

II. Problems (5 points each) Show set up for solution where appropriate

1. How many degrees does the earth rotate in 4 hours?

2. From a sun chart determine the altitude and azimuth of the sun on Dec. 21st on the 28th parallel at 10:00 AM local solar time.

    A. Altitude

    B. Azimuth

3. At a certain time the horizontal insolation rate was measured to be 230 BTU/ft^2 hr. when the solar altitude was 60 degrees at solar noon. What solar insolation (rate) would be falling on a south facing vertical wall at that time?

4. On Feb. 10th, 10:00 AM Eastern Standard Time at Atlanta, Georgia is equivalent to what local solar time?

5. A pyranometer, when facing perpendicular to the sun reads 270 BTU/ft^2 hr. What % of the total solar radiation striking the upper atmosphere has been attenuated by the atmosphere?

6. A collector, when facing the sun perpendicularly receives solar radiation at a rate of 280 BTU/ft^2 hr. Calculate the radiation rate received by the collector when tilted 30 degrees, then 60 degrees from the perpendicular condition.

A. perpendicular 280 BTU/ft^2 hr

B. + 30 degrees _______ BTU/ft^2 hr

C. + 60 degrees _______ BTU/ft^2 hr

TEST: COLLECTOR AND ENERGY STORAGE VI-103

SOLAR ENERGY CHARACTERISTICS

POST-TEST KEY

I. Matching

1. K
2. Q
3. F
4. H
5. A
6. O
7. V
8. C
9. I
10. D
11. M
12. S
13. P
14. J
15. U
16. G
17. T
18. N
19. R
20. E
21. L
22. B

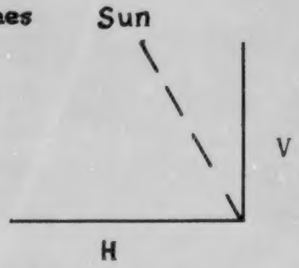
II. Problems

1. $15\ \frac{\text{degrees}}{\text{HR.}} \times 4\ \text{hr} = 60\ \text{degrees}$

2. A ≈ 30 degrees

   B ≈ 326°

3.



$$\frac{230}{\sin 60^\circ} = \frac{X}{\sin 30^\circ} \qquad X = 132.7\ \frac{\text{BTU}}{\text{ft}^2\ \text{hr}}$$

4. $84.5^\circ\ \text{W} - 75.0 = 9.5^\circ \times \frac{4\ \text{min}}{1\ \text{degree}} = 38.0$

   10:00 - 38 = 9:22

   9:22 - 12 = 9:08 AM Solar Time

5. 428 - 270 = 158

   $\frac{158}{428} = .369 \times 100 = 36.9\%$

6. A. 280

   B. 242

   C. 140

HEAT TRANSFER REVIEW

POST-TEST

I Make the best match (one point each)

____ 1. thermal conduction rate

____ 2. energy per photon

____ 3. λ x F

____ 4. free electrons

____ 5. good insulator

____ 6. R value

____ 7. U value

____ 8. density

____ 9. convection

____ 10. radiation

____ 11. specific heat

____ 12. C M ΔT

____ 13. emissivity

____ 14. absorbtivity

____ 15. transparency

____ 16. selective absorber

____ 17. selective glazing

____ 18. BTU

A. is a measure of resistance to heat flow

B. wt. per unit volume

C. low iron glass

D. BTU per lb degree

E. H x F

F. energy transfer by electromagnetic waves

G. a surface factor involved with radiation

H. speed of a wave

I. high value for collector glazing

J. unit of heat energy

K. U A ΔT

L. sensible heat equation

M. black chrome

N. conducts energy efficiently

O. high for black paint

P. coefficient of heat transmission

Q. has high (R) value

R. moving thermal energy by moving the matter containing the energy

TEST: COLLECTOR AND ENERGY STORAGE

II Problems (5 points each) (Show Problem Set Up for Solution)

1. A sheet of copper is .1 cm thick and has dimensions of 10 cm x 10 cm. A temperature difference is maintained of ($40^\circ C$) for a period of 10 min., across the face of the sheet. How many calories of heat are conducted through the copper sheet during this period of time?

2. A 300 ft^2 wall has an (R) value of 10. If a constant difference of temperature of 40° F is maintained across the different sides of the wall for 2 hrs time, how many BTU units of heat energy will conduct through the wall in that time?

3. Warm air at 95° F is circulated from rock storage to a living area at a rate of 800 ft^3 per min. The return air to the rock storage has a temperature of 83° F. Calculate the BTU/min given to the room.

   Specific heat of air .24 BTU/lb degree F.

   Ave. density of air at 13.4 ft^3 / lb.

4. An electromagnetic wave has a wave length of 4×10^{-7} meter. Calculate its energy per photon. (joule)

5. An insulated water tank containing 120 gal of water had its temperature raised from 110° F to 130° F during a six hr period by an operating solar system. Calculate the average no. of BTU units per min transferred by the circulant during the six hour operating time.

6. If the system in problem (5) used water circulating at 2 gal per min during the six hour operating period to transfer the energy from the collector to the storage tank, what average ΔT existed between the inlet and exit port (temperature) of the tank during the operating period?

7. A small sphere of dia. 20 cm is painted with a selective coating and is heated to 500° absolute. The emissivity of the coating at that temperature is .15. What is the radiation rate of the heated sphere in watts per m^2?

   Stephans Constant = 5.67×10^{-8} watt / m^2 K^4

8. If 500 ml of water at 80° C is mixed with 700 ml of water at 55° C, what equilibrium temperature will result?

HEAT TRANSFER REVIEW
POST-TEST KEY

Post-Test Answer Key

I. Matching

1. K
2. E
3. H
4. N
5. Q
6. A
7. R
8. B
9. R
10. F
11. D
12. L
13. G
14. O
15. I
16. M
17. C
18. J

II Problems

1. $H = \frac{KA(\Delta t)T}{L}$

$H = .92 \frac{\text{cal.}}{\text{cm}^{\circ}\text{C}} \times \frac{100\ \text{cm}^2 \times 40^{\circ}\ \text{C} \times 600\ \text{sec}}{.1\ \text{cm}}$

$H = 2.2 \times 10^7\ \text{cal}$

2. $H = U\ A\ \Delta T$

$H = 1/10\ \frac{\text{Btu/hr}}{\text{ft}^2\ {}^{\circ}\text{F}} \times 300\ \text{ft}^2 \times 40^{\circ}\ \text{F}$

$H = 1200\ \frac{\text{Btu}}{\text{hr}}$

$Q = H \times T$

$1200\ \frac{\text{Btu}}{\text{hr}} \times 2\ \text{hr}$

$Q = 2400\ \text{BTU}$

3. $M = V \times D$

$M = \frac{300\ \text{ft}^3}{\text{min}} \times \frac{1\ \text{lb}}{13.4\ \text{ft}^3} = 22.4\ \frac{\text{lb}}{\text{min}}$

$Q = C\ M\ \Delta T$

$\frac{.24\ \text{Btu}}{\text{Lb degree F.}} \times 22.4\ \frac{\text{lb}}{\text{min}} \times 12^{\circ}\ \text{F}$

$Q = 64.5\ \text{BTU/min}$

4. $V = \lambda \times F$

$F = \frac{V}{\lambda} = \frac{3 \times 10^{-8}\ \text{m/sec}}{4 \times 10^{-7}\ \text{m}}$

$E = F \times H$

$E = .075/\text{sec} \times 6.6 \times 10^{-34}$ joule sec

$E = .495 \times 10^{-34}$ joule

5. $Q = C\ M\ \Delta T$

$Q = \frac{1\ \text{Btu}}{\text{lb degree F.}} \times 120 \times 8.34\ \text{lb} \times 20^\circ\ \text{F}$

$Q = \frac{20 \times 10^3\ \text{Btu}}{6\ \text{hr}} = \frac{20 \times 10^3\ \text{Btu}}{6 \times 60\ \text{min}} = \frac{20 \times 10^3\ \text{Btu}}{360\ \text{min}} = 66\ \frac{\text{Btu}}{\text{min}}$

6. $Q = C\ M\ \Delta T$

$T = \frac{Q}{CM} = \frac{66\ \text{Btu/min}}{\frac{1\ \text{Btu}}{\#\text{degree F}}} \times 2 \times 8.34\ \# = \frac{66}{16.68} = 3.95^\circ\ \text{F}$

7. $\frac{P}{A} = e\ \sigma T^4$

$= .15 \times 5.67 \times 10^{-8}\ \text{watt/m}^2\ \text{K}^4 \times (5 \times 10^2\ \text{K}^\circ)^4$

$= .15 \times 5.67 \times 10^{-8} \times 645 \times 10^8$

$= 548.5\ \text{watt/m}^2$

8. Q loss = Q gained (from law of conservation of energy)

$C\ M\ \Delta T = C\ M\ \Delta T$

$1.0 \times 500 \times (80 - T_F) = 1.0 \times 700 \times (T_F - 55^\circ)$

$500 \times 80 - 500\ T_F = 700\ T_F - (700 \times 55)$

$T_F = 65.4^\circ\ \text{F}$

FLUID MECHANICS

POST-TEST

I Make the best match (one point each)

____ 1. absolute pressure

____ 2. atmospheric pressure

____ 3. pressure

____ 4. gravity head

____ 5. velocity pressure

____ 6. friction head

____ 7. fluid

____ 8. laminar flow

____ 9. turbulent flow

____ 10. viscosity

____ 11. density

____ 12. manometer

____ 13. Bernoulli Principle

____ 14. total pressure

____ 15. static pressure

A. $\sqrt{2\ A\ D}$

B. many eddy currents

C. a gas or liquid

D. wt. per unit volume

E. total pressure minus velocity pressure

F. force / area

G. measures gas pressure

H. pipe losses

I. decreases with temperature elevation

J. stream-lined flow

K. pressure referenced to a vacuum

L. manometer tube faced into the flow

M. pressure of a liquid due to its depth and density

N. pressure is low where velocity is high

O. approx. 14.7 lb/in^2 at sea level

TEST: COLLECTOR AND ENERGY STORAGE

1. A 4 inch ID water pipe is connected in series with a 6 inch ID water pipe. If the water speed in the 4 inch pipe is 5 ft/sec, calculate the water speed in the 6 inch pipe.

2. A 12 inch pipe (ID) carries water at a flow rate of 200 gal/min. What average water speed exists in the pipe? (ft/sec)

3. A circulation loop has a length of 200 ft., a pipe diameter of 2 inches and a water speed of 4 ft/sec. Its friction head is (X). The loop is extended to 500 ft and the water speed is increased to 6 ft/sec. What is the new total friction head for this system? (in reference to X)

4. What pressure is produced by a column of water that is 240 ft. in depth? (lb/in^2)

5. A duct carrying moving air registers a total pressure of .4 inches of water pressure and a static pressure of .3 inches of water. What is the average speed of the air in the duct? (Temperature of air is 80°F) (use an air velocity chart)

6. If the duct in problem (5) is circular and has a diameter of (2) ft, what is the ft^3/min capacity of the active duct?

TEST: COLLECTOR AND ENERGY STORAGE

FLUID MECHANICS

POST-TEST KEY

I Matching

1. K
2. O
3. F
4. M
5. A
6. H
7. C
8. J
9. B
10. I
11. D
12. G
13. N
14. L
15. E

II Problems

1. $D_1 \times S_1 = D_2S_2$ (inverse relationship)

   $4 \text{ in.} \times \frac{5 \text{ ft}}{\text{sec}} = 6 \text{ in.} \times X$

   $X = 3.3 \text{ ft/sec}$

2. $\frac{200 \text{ gal}}{\text{MIN}} \times 8.24 \frac{\text{lb}}{\text{gal}} = 1688 \text{ lb}$

   $\frac{1668 \text{ lb}}{\text{min}} \times \frac{1 \text{ ft}^3}{62.4 \text{ lb}} = 26.7 \text{ ft}^3$

   $V = A \times S$

   $S = \frac{V}{A} = \frac{26.7 \text{ ft}^3/\text{min}}{.785 \text{ ft}^2}$

   $S = \frac{34 \text{ ft}}{\text{min}} = .566 \frac{\text{ft}}{\text{sec}}$

3. X varies proportional to length

   X varies proportional to square of speed

   X varies inversely with diameter of pipe

   $X \times \frac{500}{200} \times \left(\frac{6}{4}\right)^2$

   $X \times 2.5 \times 2.25 =$

   X = 6.25 times original friction head

4. P = Depth x density

$$240\text{ ft} \times 62.4\ \frac{\text{lb}}{\text{ft}^3}$$

$$= 14{,}976\ \frac{\text{lb}}{\text{ft}^2} \times \frac{1\text{ ft}^2}{144\text{ in}^2} = 144\ \frac{\text{lb}}{\text{ft}^2}$$

5. Velocity pressure = Total pressure - static pressure

$V_p = .4 - .3$ inch H_2O

$V_p = .1$ inch H_2O

From velocity chart speed is read directly
speed = 1280 ft/min

6. V = A x S

$$\pi r^2 \times S$$

$$3.14 \times (1\text{ ft})^2$$

$$3.14\text{ ft}^2 \times 1280\ \frac{\text{ft}}{\text{min}}$$

$$V = 4019\ \frac{\text{ft}^3}{\text{min}}$$

FLAT PLATE COLLECTORS - POST-TEST

I Make the best match (one point each)

____	1.	glazing	A.	no circulant flow rate
____	2.	absorber plate	B.	collector testing standards
____	3.	circulant	C.	make low infiltration
____	4.	header	D.	max collector front area
____	5.	riser	E.	reveals collector performance under varying temperature conditions
____	6.	ambient temperature	F.	made from a good thermal conductor
____	7.	stagnant temperature	G.	collector tie downs
____	8.	emissivity	H.	connect headers
____	9.	high absorbtivity	I.	is an important factor in maintenance
____	10.	gross area	J.	window area
____	11.	aperture area	K.	low reflectivity
____	12.	transmittance	L.	energy output / energy input x 100
____	13.	seals and gaskets	M.	collector window
____	14.	efficiency	N.	a surface radiation factor
____	15.	efficiency curve	O.	simple pay back
____	16.	collector	P.	percent transparency of light
____	17.	durability	Q.	heat transfer fluid
____	18.	aesthetics	R.	energy can neither be created nor destroyed
____	19.	cost effectiveness	S.	outside temperature
____	20.	wind loading	T.	converts radiant energy to thermal energy
____	21.	ASHRAE	U.	main circulation channels in the collector
____	22.	conservation of energy	V.	appearances

II. Problems (5 points each)

1. List (5) important factors that determine collector efficiency during aspects of the construction of a flat plate collector.

A. ____________________

B. ____________________

C. ____________________

D. ____________________

E. ____________________

2. List at least (4) important factors associated with the installation and mounting of a given collector that will determine its performance with a given amount of solar availability.

A. ____________________

B. ____________________

C. ____________________

D. ____________________

3. List at least (1) maintenance procedure on a flat plate collector which is in operation that can improve its performance and efficiency.

____

4. List (5) important factors to consider when opting to purchase a collector.

A. ____________________

B. ____________________

C. ____________________

D. ____________________

E. ____________________

5. The insolation rate falling on a 30 ft^2 flat plate collector is 280 BTU/ft^2 hr. The temperature difference between inlet and outlet water circulant is 8 degrees (F) when the flow rate is .6 gal/min. Calculate the efficiency of this operating collector.

6. When a collector is stagnant and a constant temperature is reached internally, and is exposed to the sun, the radiant energy entering the collector window is equal to the sum of the __________, __________, and __________, energy losses from the collector.

7. Given: ambient temperature 50° F
insolation rate 270 BTU/ft^2 hr. on collector surface
collector water flow rate 1 gal/min
collector area 45 ft^2

Condition A
water inlet temperature = 118° F
water exit temperature = 126° F

Given: ambient temperature 60° F

Condition B
insolation rate 275 BTU/ft^2 hr. on collector surface
same collector as above
flow rate 1 gal/min
water inlet temperature 170° F
water exit temperature 174° F

Construct a collector efficiency curve for the above collector

8. From the graph constructed in problem (7) determine the efficiency of this collector when the inlet water temperature of the collector is equal to the ambient temperature/

9. What general statement can be made when one considers collector efficiency Vs operating temperature of the collector?

FLAT PLATE COLLECTORS

POST-TEST KEY

I Matching

1. M
2. F
3. Q
4. U
5. H
6. S
7. A
8. N
9. K
10. D
11. J
12. P
13. C
14. L
15. E
16. T
17. I
18. V
19. O
20. G
21. B
22. R

II Problems

1. A. glazing transparency
   B. box insulation
   C. conductivity of plate
   D. flow channel distances
   E. absorbtivity of absorber plate

2. A. tilt
   B. orientation (azimuth)
   C. circulant flow rate
   D. wind exposure

3. periodically clean the glazing

4. A. performance
   B. cost
   C. working life expectancy
   D. maintenance required
   E. aesthetic considerations

5. $$\text{EFF} = \frac{\text{Energy out}}{\text{Energy in}} \times 100$$

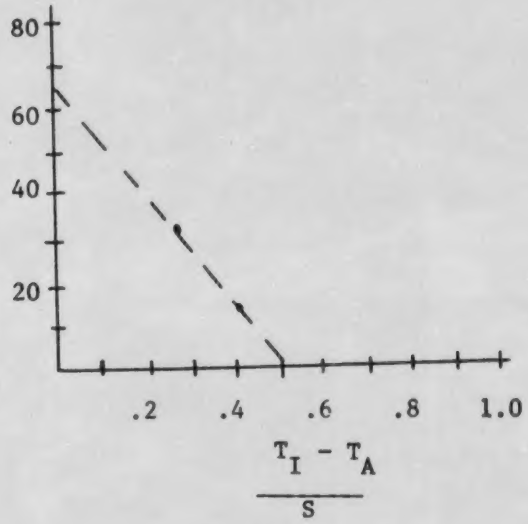
$$\text{In} \quad 30\ \text{ft}^2 \times 280\ \text{BTU/ft}^2\ \text{hr} = 8400\ \frac{\text{BTU}}{\text{HR}}$$

$$\text{Out} = C\ M\quad T = 1 \times .6 \times 8.34 \times 70 \times 8 = 2402\ \frac{\text{BTU}}{\text{HR}}$$

$$\text{EFF} = \frac{2402\ \text{BTU/hr}}{8400\ \text{BTU/hr}} \times 100 = 28.5\%$$

6. conduction, convection and radiation (any order)

7. Eff.



Part A eff. $= \frac{4003}{12,150} \times 100 = 33\%$

$$\frac{T_I - T_A}{S} = \frac{118 - 50}{270} = \frac{68}{270} = .25$$

Part B eff. $= \frac{2001}{12,375} \times 100 = 16\%$

$$\frac{T_I - T_A}{S} = \frac{170 - 60}{275} = \frac{110}{275} = .4$$

8. Approx. 65 - 70%

9. As operating temperature goes up efficiency goes down.

CONCENTRATING COLLECTORS

POST-TEST

I Make the best match (one point each)

____ 1. focus point

____ 2. concentrating ratio

____ 3. spherical reflector

____ 4. dish reflector

____ 5. trough reflector

____ 6. small acceptance angle

____ 7. absorber

____ 8. clock tracker

____ 9. photo electric tracker

____ 10. Fresnel lens

____ 11. cusp reflector

____ 12. vacuum tube collector

____ 13. V trough concentrator

____ 14. stagnant temperature

____ 15. diffuse light

A. must use small angle of aperture for sharp focus

B. single axis concentrator

C. high temperature load

D. 15° per hr.

E. for light to focus on absorber

F. may be equatorial or polar effective

G. a refractive concentrator

H. converts radiant energy to thermal energy

I. where reflected rays meet

J. double axis concentrator

K. will not focus well in concentrating applications

L. reflector ares ÷ absorber area

M. wide angle acceptance

N. small concentrating ratio

O. very high for dish concentrators

TEST: COLLECTOR AND ENERGY STORAGE

II Problems (5 points each)

1. Illustrate by side view a spherical reflector and absorber area. (use ray diagrams)

2. Illustrate by side view a parabolic reflector and the absorber area. (with ray diagram) What advantage does it have over the spherical concentrator?

3. List a prime advantage of concentrating collectors over flat plate collectors.

____

4. List at least (4) major disadvantages of concentrating collectors over flat plate collectors:

A. ____________

B. ____________

C. ____________

D. ____________

5. Illustrate by appropriate ray drawing how a Fresnel concentrator functions.

6. A dish concentrator of 70% reflectivity reflects light onto an absorber plate of 80% absorbtivity when operating at 210° F. What is the over-all efficiency of this collector? (assume no other losses)

7. List (3) practical applications of concentrating collectors:

A. ____________________

B. ____________________

C. ____________________

TEST: COLLECTOR AND ENERGY STORAGE

CONCENTRATING COLLECTORS

POST-TEST KEY

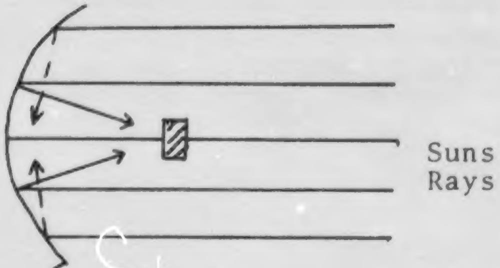
I. Matching

1. I
2. L
3. A
4. J
5. B
6. E
7. H
8. D
9. F
10. G
11. M
12. C
13. N
14. O
15. K

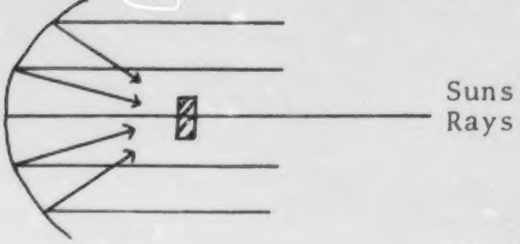
TEST: COLLECTOR AND ENERGY STORAGE

II Problems

1.



2.



All rays incident on reflector parallel to principal axis will reflect on to absorber.

3. May be more efficient at higher thermal temperature

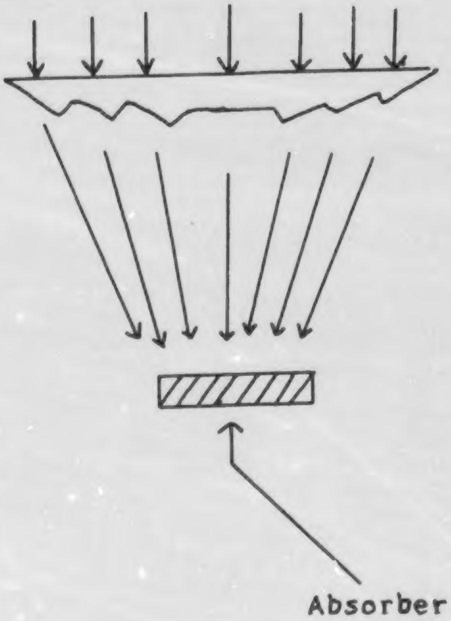
4. A. cannot use diffuse light

B. are more costly

C. must use trackers

D. more maintenance needed

5.



6. .7 x .8 = .56 = 56% eff.

7. A. Solar air conditioning
   B. Process at eam
   C. Rankine cycle engines

SOLAR STORAGE

POST-TEST

I Make the best match (one point each)

____	1.	heat of fusion (water)	A.	aluminum foil
____	2.	heat of vaporization (water)	B.	C M Δ T
____	3.	sensible heat	C.	top of tank is warmer than bottom
____	4.	specific heat	D.	252 calories
____	5.	volume to area ratio	E.	1st consideration in design
____	6.	infrared-red reflector	F.	BTU/lb °F
____	7.	one BTU	G.	second consideration in design
____	8.	rock storage	H.	located near the south wall window
____	9.	collector efficiency	I.	north wall
____	10.	tank stratification	J.	should be high for minimum losses
____	11.	trombe wall	K.	degrees per ft
____	12.	slab storage	L.	144 BTU/lb
____	13.	temperature gradient	M.	U A Δ T
____	14.	tank to load sizing	N.	minimum maintenance
____	15.	tank to collector sizing	O.	determined by operating temperature
____	16.	thermal conduction rate	P.	970 BTU/lb
			Q.	lots of thermal mass

TEST: COLLECTOR AND ENERGY STORAGE

II Problems

1. List at least (6) major factors to consider on storage type and capacity to be used:

A. ____________________

B. ____________________

C. ____________________

D. ____________________

E. ____________________

F. ____________________

2. Why is storage location important (3 reasons)?

A. ____________________

B. ____________________

C. ____________________

3. In a DHW solar application, what volume of water storage would be appropriate for a family of (5)?

4. In problem (3) with optimum flat plate collector tilt and orientation, what area would be needed when January insolation rate is 1200 BTU/ft^2 day and ground water temperature is 60° F. and use temperature is 120° F. and 70% of hot water load is to be handled by solar? (ft^2) (no exchanger)

5. A water tank of dimensions 5 ft. x 8 ft. x [illegible] ft. is used for thermal storage in a space heating application. If the beginning tank temperature is 130° F. and the final tank temperature 115° F., how many BTU units were removed from the tank?

6. Calculate the amount of thermal energy absorbed when 48 ft^3 of calcium chloride is melted at its melting point.

7. A rock storage bin of dimensions 6 ft. x 6 ft. x 6 ft. contains rock making up 70% of its volume. The rock density approximates 140 lb/ft^3 and has a specific heat of .2 BTU/lb $^{\circ}$F. If during a sunny day the average temperature increase of the rock storage amounted to 35° F., how many BTU were put into storage that day?

SOLAR STORAGE

POST-TEST KEY

I Matching

1. L
2. P
3. B
4. F
5. J
6. A
7. D
8. N
9. O
10. C
11. H
12. Q
13. K
14. E
15. G
16. M

II Problems

1. A. location D. maintenance
   B. load type E. size
   C. cost F. accessibility

2. A. collector proximity
   B. load location
   C. piping choices (air - water etc.)

3. 20 gal/person for first (2)

15 gal per person beyond (2)

85 gal

4. $1.0 = \frac{A\ S}{L}$ (from graph)

$$A = 1.0 \times \frac{L}{S} = \frac{1.0\ (C\ M\ \Delta T)}{1200}$$

$$A = 1.0 \times \frac{42{,}534\ \text{BTU}}{1200\ \text{BTU/ft}^2}$$

A = 35 ft^2 (collector)

S = average daily insolation rate (January)

L = Jan. daily thermal DHW load by family

5. 5 ft x 8 ft x 6 ft = 240 ft^3

240 ft^3 x 62.4 lb/ft^3 = 14,976 lb

Q = C M ΔT

= 1 x 14,976 x 15

Q = 224,640 BTU

C = BTU/lb °F

M = lb

T = °F

6. Heat of fusion calcium chloride = 63.2 BTU/lb

= 7570 BTU/ft^3

48 ft^3 x 7570 BTU/ft^3 = 236,360 BTU

7. 6 ft x 6 ft x 6 ft = 216 ft^3
216 ft^3 x .7 rock = 151.2 ft^3 rock

151.2 ft^3 x 140 lb/ft^3 = 21.168 lb rock

Q = C M ΔT

.2 BTU/lb °F x 21,168 lb x 35° F

Q = 148,176 BTU stored per day

BASIC SOLAR SYSTEMS

POST-TEST

I Make the best match (one point each)

____	1. Bread Box DHW	A. uses electric hydronic valves to operate
____	2. thermosiphon system	B. uses a green-house
____	3. direct recirculation	C. needs expansion tank
____	4. direct drain down	D. has no freezing problems
____	5. indirect drain back	E. tank in box as pre-heater
____	6. closed loop	F. clerestory utilization
____	7. hybrid	G. high volume flow rate through the collector
____	8. pool system	H. very effective
____	9. two tank system	I. minimum freeze conditions
____	10. in tank exchanger	J. needs huge area
____	11. external heat exchanger	K. needs high head pump
____	12. air collector	L. tank must be higher than collector
____	13. pool collector	M. contains active and passive features
____	14. direct gain	N. often needs two pumps
____	15. indirect gain	O. solar system used as a pre-heater

TEST: COLLECTOR AND ENERGY STORAGE

II Problems

1. List at least 10 major components of a Solar DHW System:

A. ____________________

B. ____________________

C. ____________________

D. ____________________

E. ____________________

F. ____________________

G. ____________________

H. ____________________

I. ____________________

J. ____________________

2. List two major advantages of a recycle freeze protection DHW System:

A. ____

B. ____

3. List (3) major advantages of a single closed loop solar DHW:

A. ____

B. ____

C. ____

4. List at least two major disadvantages of a single closed loop solar DHW:

A. ____

B. ____

5. List (2) major advantages of a closed loop drain back solar DHW System:

A. ____

B. ____

6. Which solar system type is most likely to be the least expensive to install and yet be the most cost effective for a small fraction of the DHW load and to be the most maintenance free?

7. Where are the two controller sensors located on a typical Solar DHW System

   A. ____

   B. ____

8. Which type solar system often operates within a few degrees of the ambient air temperature?

BASIC SOLAR SYSTEMS

POST-TEST KEY

I Matching

1. E
2. L
3. I
4. A
5. K
6. C
7. M
8. G
9. O
10. H
11. N
12. D
13. J
14. F
15. B

II Problems

1. A. pump

   B. check valve

   C. P-T valve

   D. collectors

   E. Differential controller

   F. isolation valves

   G. automatic air valve

   H. isolation valve

   I. sensors

   J. heat transfer fluid

2. A. more efficient than closed loop

   B. less costly

3. A. positive freeze protection

   B. no collector mineralization

   C. uses in tank exchanger

4. A. more expensive than recycle

   B. must use an exchanger

5. A. can use water as primary circulant

   B. no check valve needed

6. Bread box solar pre-heater

7. A. On exit line of collector

   B. near bottom of storage tank

8. A Solar Pool Heating System

HYDRONIC SYSTEM COMPONENTS

POST-TEST

I Make the best match (one point each)

____	1.	circulating pump	A.	located near the tank
____	2.	tempering valve	B.	permits thermal energy transfer across physical barrier
____	3.	isolation valves	C.	isolates air out of closed loop
____	4.	P-T valve	D.	often located on solar storage tank
____	5.	pressure relief valve	E.	reduces thermal losses
____	6.	check valve	F.	often used in drain down systems
____	7.	three way valve	G.	measures flow rate of circulant
____	8.	automatic air valve	H.	usually on the solar loop near collector
____	9.	heat exchanger	I.	electric operated water valve
____	10.	differential controller	J.	turns pump off and on
____	11.	flow meter	K.	often magnetically driven
____	12.	flat plate collector	L.	permits water drain down from the solar loop
____	13.	pipe insulation	M.	prevents reverse thermosiphoning
____	14.	solenoid valve	N.	converts solar radiative energy into thermal energy
____	15.	air separator	O.	mixes hot and cold water

II Problems

1. Indicate the basic function for each of the listed hydronic components below:

A. isolation valves

B. check valve

C. differential controller

D. automatic air valve

E. solenoid valves

2. List the basic hydronic components needed in a closed loop drain back system:

A. ____________________

B. ____________________

C. ____________________

D. ____________________

etc. ____________________

3. What is the advantage in using a magnetically driven impeller in a circulating pump?

4. What is the basic advantage of using motorized check valve versus a ball check valve?

5. What basic function does an air expansion tank have when utilized in a closed loop system?

6. What is the difference between a low and high head pump?

7. Why shouldn't two different metals be used in a solar circulation loop if they are not isolated?

TEST: COLLECTOR AND ENERGY STORAGE

HYDRONIC SYSTEM COMPONENTS

POST-TEST KEY

I Matching

1. K
2. O
3. A
4. D
5. H
6. M
7. F
8. L
9. B
10. J
11. G
12. N
13. E
14. I
15. C

II Problems

1. A. Isolation valves are used to separate the solar loop from the rest of the plumbing system

   B. Check valves stop reverse thermosiphoning

   C. Differential controller turns circulating pump off and on

   D. Automatic air valve permits air elimination from the loop as well as manual drain down of the loop

   E. Solenoid valves are electric switching valves often used in drain down systems

2. A. circulating pump

   B. expansion tank

   C. in-tank heat exchanger

   D. differential controller

3. Water doesn't contact the motor impeller, no leaks through seals, etc.

4. They don't stick as often since they are spring loaded.

5. Allows heat transfer fluid to expand in the system without over pressurization or overflow.

6. A low head pump is used for circulation and will only pump water vertically only a few feet, a high head pump can pump water vertically a great number of feet.

7. If circulant becomes slightly acidic, voltaic corrosion will result.

HEAT EXCHANGERS

POST-TEST

I Mark (+) for true and (0) for false (2 points each)

____ 1. A heat exchanger allows thermal conduction through a physical barrier.

____ 2. A parallel flow heat exchanger is usually more effective than a counter flow exchanger.

____ 3. A double wall exchanger must be used to isolate toxic circulants from potable water.

____ 4. A double wall exchanger is less effective as a heat exchanger than is a single wall.

____ 5. A coil in tank heat exchanger represents a highly effective form of an exchanger.

____ 6. As a general rule, the larger the conducting mass in an exchanger the more effective it is functionally.

____ 7. In rock storage used in space heating an air to air exchanger is functioning.

____ 8. In solar air systems an air to water exchanger is often used for pre-heating DHW.

____ 9. A fan coil is representative of a water to air exchanger.

____ 10. As a general rule the larger the conducting surface area of an exchanger has the more effective it will be.

____ 11. All other factors held constant, a copper exchanger will be more effective than one made of aluminum.

____ 12. A heat exchanger used on the collector loop should be highly effective in order to permit the collector to operate at as low a temperature as possible to yield the highest efficiency of performance for the collector.

____ 13. When contemplating heat exchanger options, careful study of the product literature is a must to determine maximum effectiveness for the most reasonable cost.

____ 14. All heat exchangers have limiting features concerning the circulants used in them, the flow rates through them and the maximum pressures that they can be safely used in.

TEST: COLLECTOR AND ENERGY STORAGE

II Problems (5 points each)

1. Illustrate by drawing a solar collector and in-tank heat exchanger utilized with a single closed loop. (water to water)

2. Illustrate with a drawing a dual loop external counter flow heat **exchanger** linking collector loop with storage loop. (water to water)

3. Illustrate with a drawing a solar loop to storage and storage to fan coil for space heating. (water to air system)

4. A fan coil when in operation has a water circulation rate of 3 gal/min. Its input water temperature is measured at 130° F. and exit temperature is measured at 105° F. Calculate the BTU units per hr. given to the air going through the fan coil.

5. The air flow through the fan coil is 1200 ft^3/min. What elevation in temperature did the air experience in going through the fan coil?

   Specific heat of air is .24 BTU/lb degree F.

   Density of air is 13.4 ft^3 / lb

   (Refer to Problem 4)

6. In illustration (2) the flow rate through the collector and loop (1) of the exchanger was measured at 2 gal/min with a ΔT of 30° across the collector. In the exchanger to the tank loop, the flow rate was 3.5 gal/min. Calculate the ΔT of the water in loop (2) as it goes through the tank.

TEST: COLLECTOR AND ENERGY STORAGE

HEAT EXCHANGERS

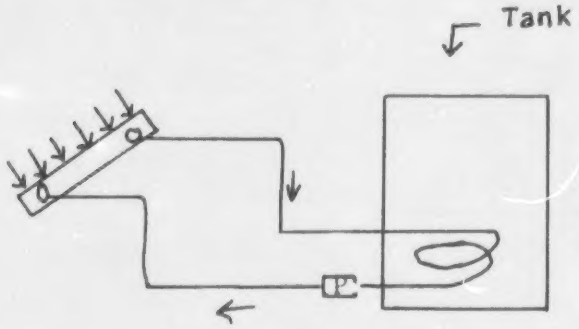
POST-TEST KEY

I True or False

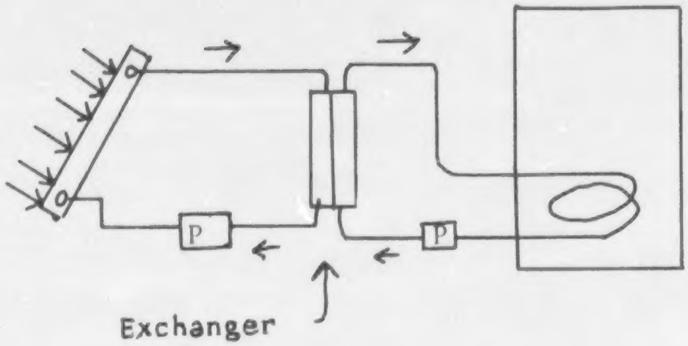
1. +
2. 0
3. +
4. +
5. +
6. +
7. +
8. +
9. +
10. +
11. +
12. +
13. +
14. +

II Problems

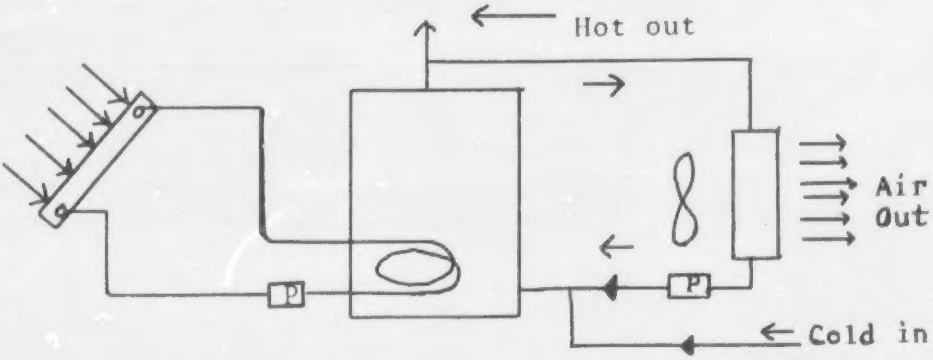
1.



2.


P
P
Exchanger

3.


Hot out
Air Out
P
P
Cold in

4. Q = C M ΔT

1 x 3 x 8.34 x 60 x 25

Q = 37,530 BTU

5. $Q = C\ M\ \Delta T$

$$\Delta T = \frac{Q}{C\ M} = \frac{37{,}530 \text{ BTU/hr}}{.24 \frac{\text{BTU}}{\text{lb}^\circ\text{F}} \times 5370 \text{ lb/hr}} = \frac{37{,}530}{1289} = 29^\circ \text{ F.}$$

$$1200 \frac{\text{ft}^3}{\text{MIN}} \times \frac{60 \text{ min}}{\text{hr}} = 72{,}000 \frac{\text{ft}^3}{\text{hr}} \times \frac{1 \text{ lb}}{13.4 \text{ ft}^3} = 5373 \frac{\text{lb}}{\text{hr}}$$

6. $C\ M\ \Delta T$ (of solar loop) $= C\ M\ \Delta T$ (of tank loop) From Law of Conservation of energy

$$2 \times 8.34 \times 30 = 3.5 \times 8.34 \times \Delta T$$

$$2 \times 30 = 3.5\ \Delta T$$

$$\frac{60}{3.5} = \Delta T$$

$$17.1\ ^\circ\text{F} = \Delta T$$

HEAT TRANSFER FLUIDS

POST-TEST

I Mark (+) for true and (0) for false (2 points each)

____ 1. Every heat transfer fluid has good and bad properties about its make-up and therefore should be chosen relative to a particular application.

____ 2. The specific heat of water is high relative to other heat transfer fluids.

____ 3. Glycol solutions when applied to solar applications usually will last for the life of the system.

____ 4. High stagnant temperature in collector promotes the degradation of some common heat transfer fluids.

____ 5. Silicone heat transfer fluids are less viscous than glycol solutions and may seep through poorly soldered piping joints.

____ 6. One distinct advantage of closed loop systems involving special heat transfer fluids is that no mineralization occurs on the inside piping of a collector since the same fluid is constantly circulated when the system is in operation.

____ 7. One distinct disadvantage of a closed loop system involving a toxic heat transfer fluid is the need to use a double walled exchanger when coupled to the potable water supply.

____ 8. Water is an excellent heat exchange fluid but freezes, may be slightly corrosive, and has a moderately low boiling point.

____ 9. A big disadvantage of silicone heat transfer fluids is that it is so expensive.

____ 10. A silicone based heat transfer fluid requires less maintenance than most any other heat transfer fluid available.

____ 11. Connecting pipe sizing and or flow speeds must be adjusted in some occasions when substitutions in the heat transfer fluid is made.

____ 12. The chemical compatibility of the heat transfer fluid with the total circulation loop make-up, must be considered for long term functioning.

TEST: COLLECTOR AND ENERGY STORAGE

II Problems (5 points each) (Show solution set-up)

1. List three good and three bad properties of water as a heat exchange fluid.

Good	Bad
A. ____________________	A. ____________________
B. ____________________	B. ____________________
C. ____________________	C. ____________________

2. A 1/2 inch ID copper pipe is used to transfer thermal energy from a collector to storage via a closed loop, with a flow rate of 2 gal/min. of water with a 20 degree ΔT across the collector. A silicone heat transfer fluid of about the same density as water and with a specific heat of .4 BTU/lb degree is going to be substituted for water as the heat exchange fluid. What flow rate is needed with the silicone fluid to keep the ΔT across the collector the same under the same insolation conditions? (gal/min)

3. List (5) special advantages of using silicone heat transfer fluids:

A. ______________________

B. ______________________

C. ______________________

D. ______________________

E. ______________________

4. List two special properties of a good heat exchange fluid that make it good for long term use:

A. ______________________

B. ______________________

5. List at least two notable disadvantages of using a low boiling point heat transfer fluid in a closed loop system.

A. ______________________

B. ______________________

TEST: COLLECTOR AND ENERGY STORAGE

HEAT TRANSFER FLUIDS

POST-TEST KEY

I True or False

1.	+
2.	+
3.	0
4.	+
5.	+
6.	+
7.	+
8.	+
9.	+
10.	+
11.	+
12.	+

II Problems

1. Good A. high specific heat

B. low viscosity

C. costs little

Bad D. will freeze and expand at 32° F

E. will promote corrosion

F. moderately low boiling point

2. $\frac{1}{.4}$ = 2.5 times higher specific heat for water

$2 \frac{\text{gal}}{\text{min}} \times 2.5 = 5$ gal/min

3. A. non- toxic
   B. low viscosity
   C. very stable
   D. high boiling point
   E. does not promote corrosion

4. A. good stability
   B. does not promote corrosion

5. A. Higher temperature will promote vapor locks in circulation loop
   B. Liquid will tend to boil off and have to be replaced

AIR DISTRIBUTION COMPONENTS

POST-TEST

I Mark (+) for true and (0) for false (2 points each)

____ 1. A centrifugal blower usually produces the pressure difference needed to make air move through a duct system.

____ 2. The greater the speed of air in a duct system the greater the friction induced pressure drop will be all other factors held constant.

____ 3. Intake areas are low pressure areas associated with a duct work system.

____ 4. A motorized damper provides an electrically controlled means of switching air flow routes in a duct system.

____ 5. Velocity pressure of air in a duct can be easily converted graphically to air speed if the temperature of the air is known.

____ 6. Total pressure minus static pressure equals velocity pressure.

____ 7. A manometer is a density measuring device.

____ 8. Turbulence in a central duct system promotes friction head losses.

____ 9. All components interrupting the main duct work contribute to greater friction head losses.

____ 10. Filters promote high resistance in air flow channels and therefore should be replaced or cleaned regularly.

____ 11. A back draft damper allows air to move in either direction through that part of the air channel.

____ 12. Tight bends in air ducts promote low resistance effects.

____ 13. Air speed times cross-section area of the duct yields the lb / min air flow.

____ 14. Vane meters are air speed measuring meters.

____ 15. When air leaves an air supply duct it is being compressed and thus slows down.

TEST: COLLECTOR AND ENERGY STORAGE

II Problems (5 points each)

1. A fan when operating can move 400 ft^3 / min of air through its whirling blades. How many lbs of air will move through the fan in one hours time? (use density of air as 1 lb / 13.4 ft^3)

2. A circular air duct 2 ft in diameter carries air at 1,000 ft^3 / min. Calculate the average speed of the air moving in the duct. (in ft / min)

3. A manometer in an active air duct measures a total pressure of .5 in of water and a static pressure of .2 in of water. If the air temperature is 120° F., what is the average air speed in the duct? (ft/min) (note air velocity chart)

4. An air duct system which is circular in configuration has a diameter of (2 ft) and carries air from some air solar collectors at 1,000 ft/min at a temperature of 120° F. to rock storage and then cycled back to the collectors at a temperature of 95° F. Calculate the no. of BTU units per min that are given to the rock storage.

5. Illustrate by drawing how a simple manometer can be used to measure:

   A. Total pressure in an active duct

   B. Static pressure in an active duct

TEST: COLLECTOR AND ENERGY STORAGE

AIR DISTRIBUTION COMPONENTS

POST-TEST KEY

I True or False

1. +
2. +
3. +
4. +
5. +
6. +
7. 0
8. +
9. +
10. +
11. 0
12. 0
13. 0
14. +
15. 0

II Problems

1. $$400\ \frac{ft^3}{min} \times 60\ \frac{min}{hr} \times \frac{1\ lb}{13.4\ ft^3} = 1791\ \frac{lb}{hr}$$

2. $V = A \times S$

$$S = \frac{V}{A} = \frac{1 \times 10^3\ ft^3/min}{3.14\ ft^2} = 318\ \frac{ft}{min}$$

3. Velocity pressure = Total pressure minus static pressure

V_p = .5 in. - .2 in. = .3 in. water

From air velocity chart, air at 120° F and a velocity pressure of .3 in. of water has a speed of 2500 ft/min.

4. $V = A \times S$

$$= 3.14\ ft^2 \times 1 \times 10^3\ ft/min \qquad M = \frac{3.14 \times 10^3\ ft^3}{13.4\ ft^3/lb}$$

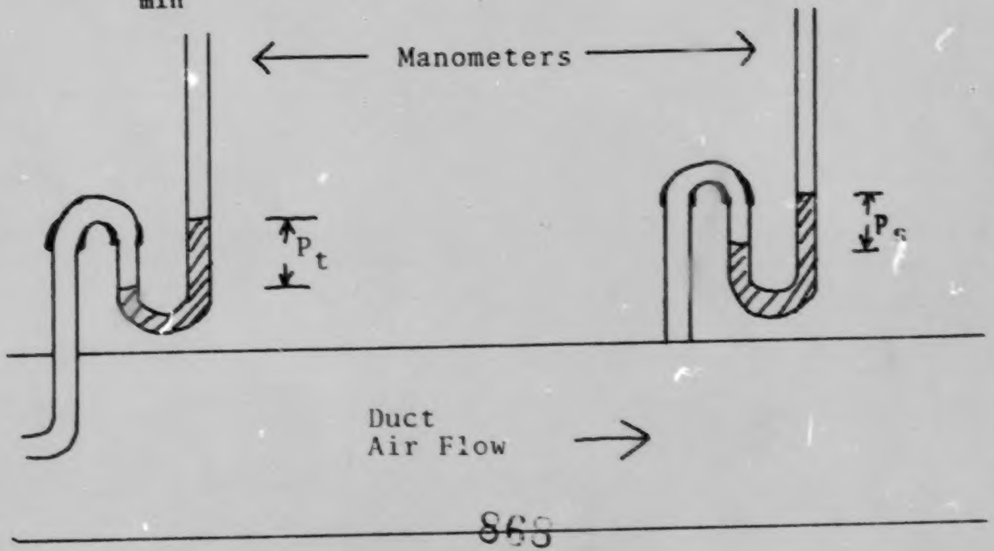
$V = 3.14 \times 10^3\ ft^3/min$

$Q = C\ M\ \ T$

$$= .24 \times 74.6\ \frac{lb}{min} \times 25 = 447\ BTU/min$$

5.

A.



TEST: COLLECTOR AND ENERGY STORAGE VI-173

CONTROLS AND CONTROL DEVICES

POST-TEST

I Mark (+) for true and (0) for false (2 points each)

____ 1. A bimetal sensor functions on the principle of differences of coefficient of expansion.

____ 2. A thermocouple produces a small electric current proportional to the difference of temperature between two junctions.

____ 3. Pressure and temperature relief valves are basically safety valves for the system.

____ 4. A thermostat circuit is a high energy circuit.

____ 5. The resistance of a thermistor increases with an increase in temperature.

____ 6. A typical differential controller will turn on with a temperature difference of 4° F. and off with a temperature difference of 18° F. between its two sensors.

____ 7. A thermopile is a number of thermocouples connected in series.

____ 8. The collector sensor for the differential controller is usually located on the exit pipe of the collector near the collector box.

____ 9. The tank sensor for the differential controller is usually located near the upper third of the tank.

____ 10. Motorized dampers are usually triggered by thermostat circuits.

____ 11. A relay is often used by a low energy circuit to turn off or on a high energy circuit and component.

____ 12. Aquastats are temperature controlled valves often inline.

____ 13. If a collector sensor circuit becomes broken the circulating pump will turn on.

____ 14. If the tank sensor circuit is shorted, the pump will turn off.

____ 15. Solenoids are electric water valves.

____ 16. A check valve permits water to flow in one direction only.

____ 17. Multi stage thermostats are often used with solar systems also using a back-up system.

____ 18. Timers are usually simple switching devices that are often inexpensive and reliable.

____ 19. A mixing valve prevents stagnation temperature from getting too high in a collector.

____ 20. Limit switches are often used as safety devices on furnace applications.

____ 21. A thermostat controlled solar loop is usually less efficient but requires less maintenance than one controlled by a differential controller.

____ 22. Solenoid valves often stick after being in service for a few years and are expensive to purchase.

II **Problems** (5 points each)

1. The "turn on" temperature differential used with a differential controller is often near ___?___ degrees.

2. The "turn off" temperature differential used with a differential controller is often near ___?___ degrees.

3. Assuming a linear response, if a temperature difference of 30 degrees between junctions of a thermocouple produce a voltage of 5 milli volts then a temperature difference of 50 degrees between junctions will produce ___?___ milli volts.

4. In passive design, shutters, awnings and moveable insulation are good energy control devices. Please explain.

   A. shutters ______________________________

   B. awnings ______________________________

   C. moveable insulation ______________________________

5. List (3) passive energy transfer modes for a solar air system:

   A. ____________ to ____________

   B. ____________ to ____________

   C. ____________ to ____________

CONTROLS AND CONTROL DEVICES

POST-TEST KEY

I True or False

1. +
2. +
3. +
4. 0
5. 0
6. 0
7. +
8. +
9. 0
10. +
11. +
12. +
13. 0
14. +
15. +
16. +
17. +
18. +
19. 0
20. +
21. +
22. +

II Problems

1. 18 degrees

2. 4 degrees

3. 8.3 milli volts

4. A. control insolation into window

   B. control insolation into window

   C. used at night to lessen loss through window

5. A. collector to load

   B. collector to storage

   C. storage to load

BASIC DHW SIZING

POST-TEST

I Mark (+) for true and (0) for false (2 points each)

____ 1. To size the thermal load needed for a residential dwelling both the DHW as well as the space heating load must be considered.

____ 2. Solar Energy can often contribute 95179 of the total thermal load cost effectively.

____ 3. Ground water temperature, use temperature and number of people in the household are three critical variables to be used in calculating DHW load.

____ 4. Storage capacity for solar contribution is often sized for one weeks energy usage.

____ 5. After the thermal load is determined, good design procedure requires the proper sizing of storage then collector area be accomplished.

____ 6. DHW thermal storage often approximates 15 - 20 gal. of hot water per person per day.

____ 7. Space heating load is determined partially by using these factors:

A. heating degree days (local weather effect)
B. solar availability
C. window area and location
D. size of the dwelling
E. R-value of insulation in walls and ceiling
F. infiltration factors of the home

____ 8. Family life style has little to do with thermal load requirements of a household.

____ 9. Conservation practices may contribute to considerable less energy usage in a household.

____ 10. The January average daily insolation rate is often used in determining the size of solar collector to use for the household.

____ 11. Pipe sizes and flow rates are critical sizing considerations in linking collector to load and load to storage.

____ 12. A flow rate of .6 to 1 gal/min per 30 ft^2 of collector is often used as a rule of thumb sizing ratio.

____ 13. An air collector should have an air flow rate of about 2 ft^3 per min per ft^2 of collector.

____ 14. Since the specific heat of rock is only about .2 of that of water, it requires about 5 times the mass of rock to store the equivalent amount of heat as water.

____ 15. Solar collector area sizing is centered around insolation averages for a particular region. On any given year, the actual solar insolation availability may vary considerably from these averages.

II Problems (5 points each) (Show solution set up)

1. Given: 5 people in household (20 gal/person)

   ground water temperature 60° F.

   use water temperature 122° F.

   ? daily BTU load for DHW

2. A central duct air system with dimensions of 2 ft x 3 ft is to circulate air to a room of dimensions 40 ft x 60 ft x 10 ft. The room air is to be exchanged once every 10 min. What average air speed must be in the main duct to accomplish this ventilation requirement?

3. In order to operate efficiently a collector must operate in maximum solar flux conditions with a ΔT of 30° across the collector. If the collector is to deliver 10,000 BTU per hr to storage with the ΔT of 30°. What water flow rate in gal/min is needed to perform this feat?

4. In problem (3) if a 1/2 inch ID pipe is used to carry the flow, what flow speed for the water is needed? (ft/sec)

5. A water tank, cylindrical in shape has an end diameter of 10 ft and is 15 ft long. It contains water at a temperature of 130° F. A space heating **fan** coil is tied to this hot water storage and when operating yields 20,000 BTU per hr to the air space. How long would the fan coil operate to lower the temperature of the water in the storage tank 5° F.? (hrs.)

TEST: COLLECTOR AND ENERGY STORAGE

BASIC DHW SIZING

POST-TEST KEY

I **True or False**

1. +
2. 0
3. +
4. 0
5. +
6. +
7. +
8. 0
9. +
10. +
11. +
12. +
13. +
14. +
15. +

II Problems

1. $Q = C\ M\ \Delta T$

$= 1 \times 100 \times 8.34 \times 62$

$Q = 51{,}708$ BTU/day

2. $V = A \times S$

$$S = \frac{V}{A} = \frac{24{,}000\ \text{ft}^3/10\ \text{min}}{6\ \text{ft}^2}$$

$$S = \frac{2400\ \text{ft}^3/\text{min}}{6\ \text{ft}^2} = 400\ \text{ft/min}$$

3. $Q = C\ M\ \Delta T$

$$M = \frac{Q}{C\Delta T} = \frac{10{,}000\ \text{Btu/hr}}{1 \times 30^\circ\ \text{F} \times \text{Btu/lb degree}}$$

$M = 333.3$ lb/hr

$$m = 333.3\ \text{lb/hr} \times \frac{1\ \text{gal}}{8.34\ \text{lb}} = 39.96\ \text{gal/hr}$$

$$M = 39.96\ \frac{\text{gal}}{\text{hr}} \times \frac{1\ \text{hr}}{60\ \text{min}} = .666\ \text{gal/min}$$

4. $V = A \times S$

$$S = \frac{V}{A} = \frac{.089\ \text{ft}^3/\text{min}}{1.36 \times 10^{-3}\ \text{ft}^2}$$

$.66$ gal/min $\times$ 8.34 lb/gal $= 5.5$ lb/min

$$5.5\ \text{lb/min} \times \frac{1\ \text{ft}^3}{62.4\ \text{lb}} = .089\ \text{ft}^3/\text{min}$$

$$S = 65.4\ \text{ft/min} \times \frac{1\ \text{min}}{60\ \text{sec}}$$

$S = 1.09$ ft/sec

5. $V = \pi R^2 L$

$3.14 \times (5)^2 \times 15$

$V = 1177.5\ \text{ft}^3 \times 62.4\ \text{lb/ft}^3 = 73{,}476\ \text{lb}$

$Q = C\ M\ \Delta T$

$1 \times 73{,}476 \times 5$

$Q = 367{,}380\ \text{BTU}$

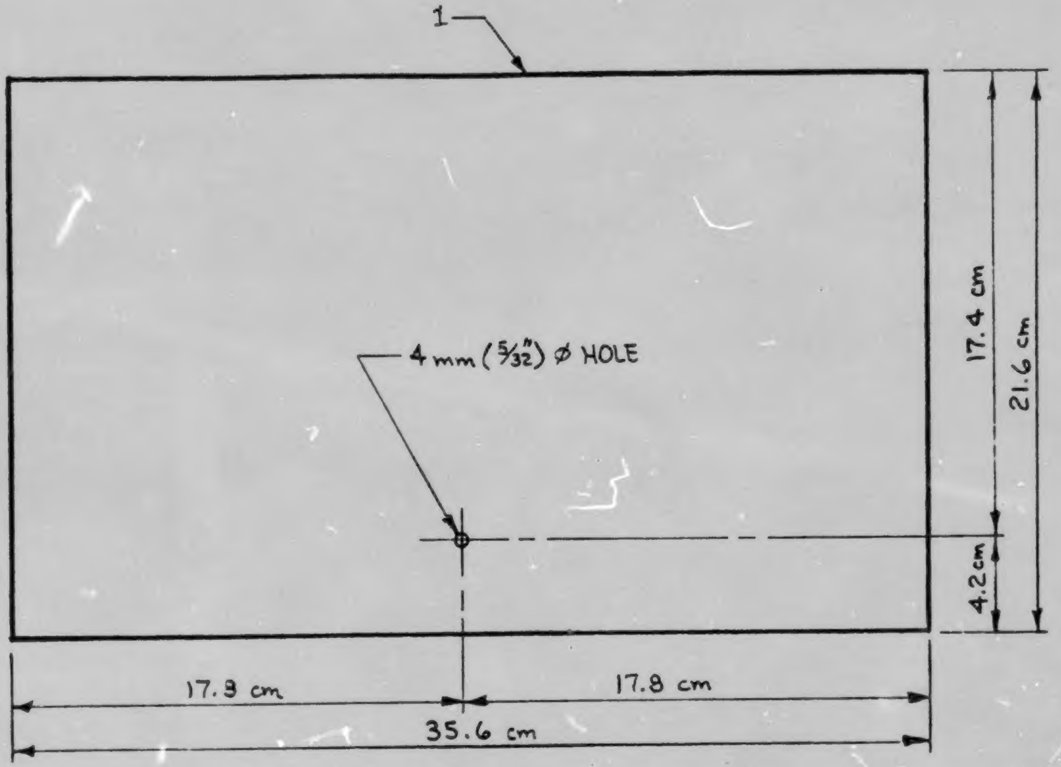
$$367{,}380\ \text{Btu} \times \frac{1\ \text{hr}}{2 \times 10^4\ \text{Btu}} = 18.37\ \text{hr}$$

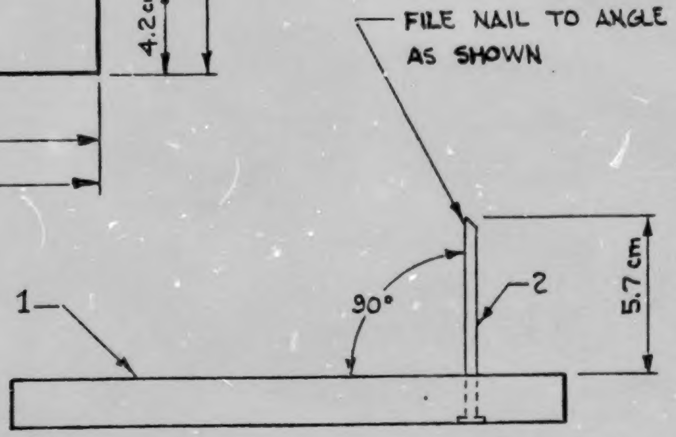
COLLECTORS AND ENERGY STORAGE

Overhead

Transparency

Masters


1
4 mm (5/32") ⌀ HOLE
17.4 cm
21.6 cm
4.2 cm
17.8 cm
17.8 cm
35.6 cm

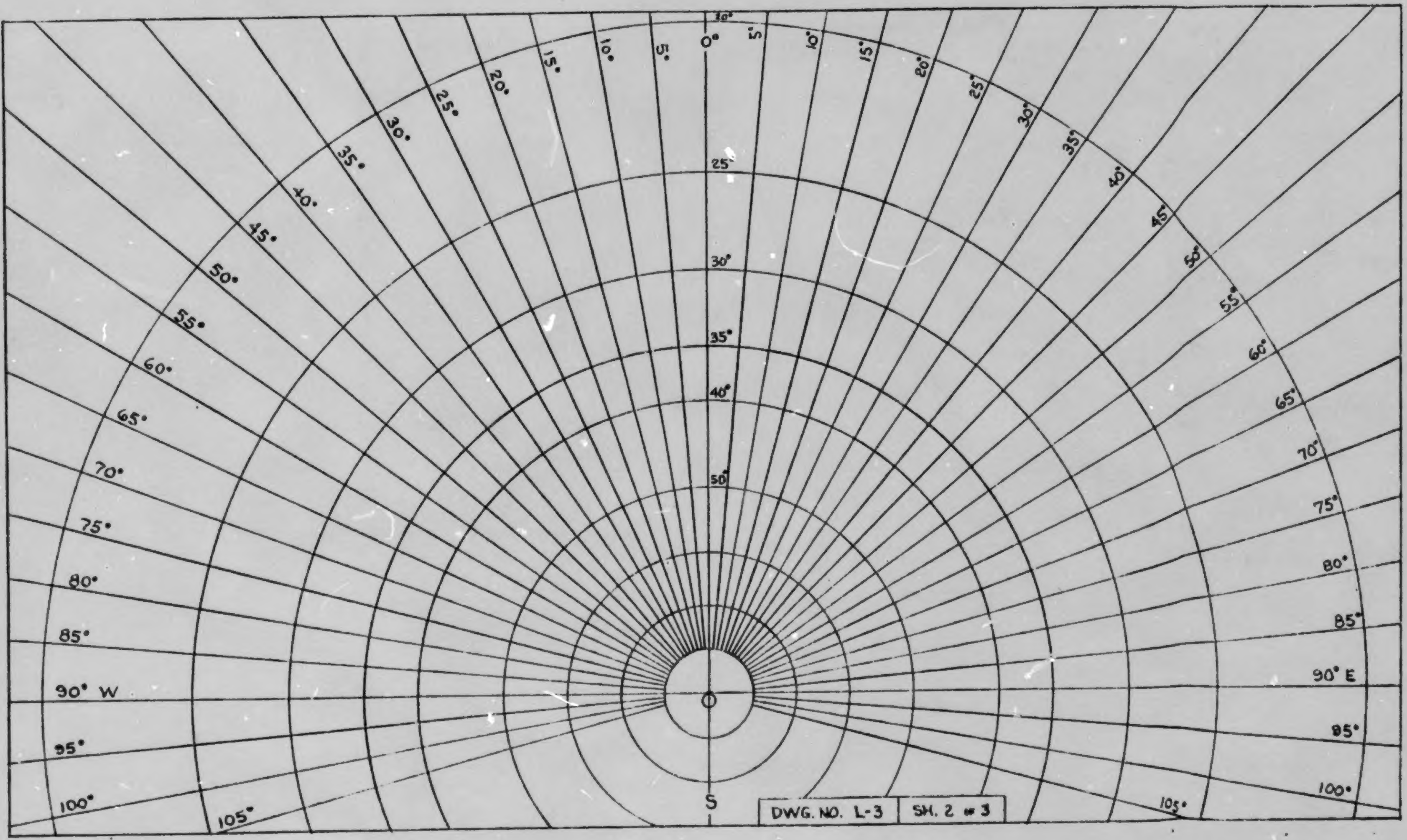

FILE NAIL TO ANGLE AS SHOWN
90°
1
2
5.7 cm

END VIEW - AFTER ASSEMBLY

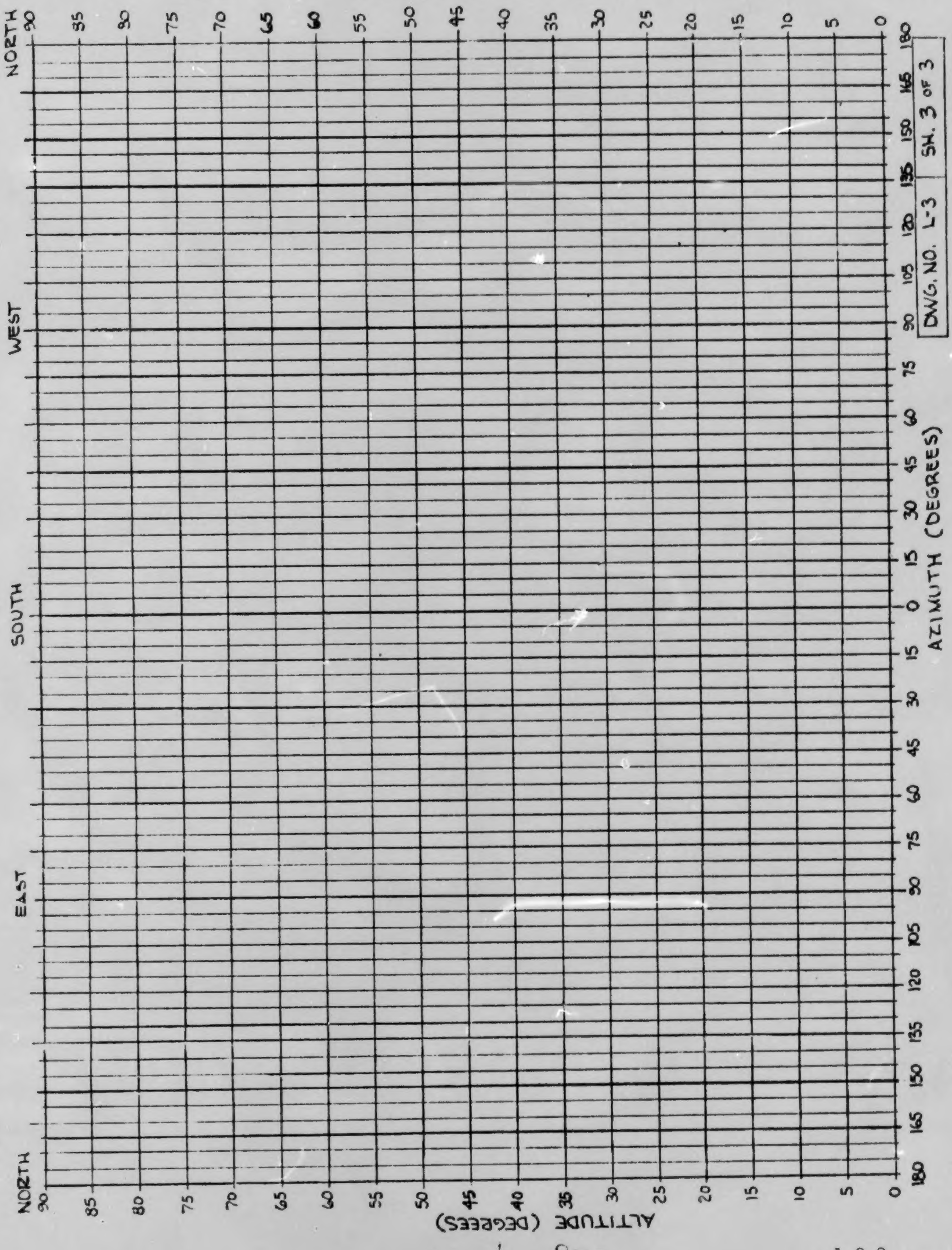
PART NO.	NAME & DESCRIPTION	
1	SHADOW BOARD	3/4" BIRCH PLYWOOD
2	SHADOW POLE	16 d COMMON NAIL

NAVARRO COLLEGE, SOLAR ENERGY DIV.		ALTITUDE/AZIMUTH SHADOW BOARD	DWG. NO. L-3
SCALE: NONE	DATE: 10-30-79	DR. BY: CM	CK. BY: HAB	SH. 1 OF 3

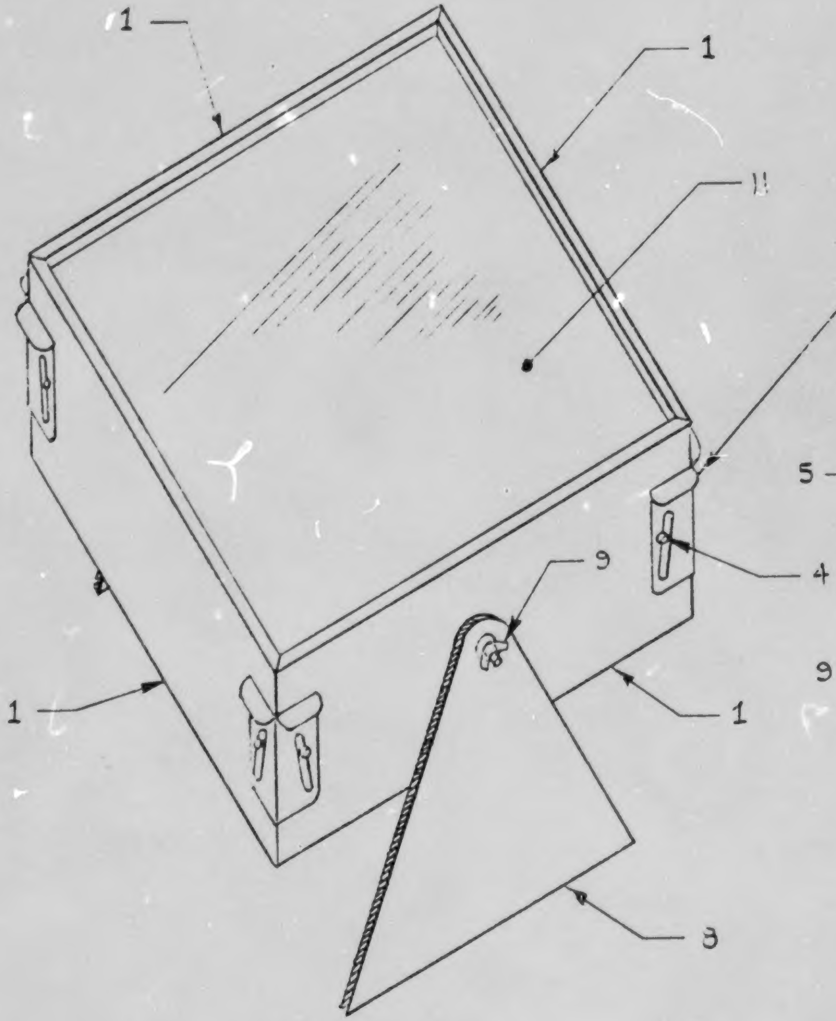
L-3-1

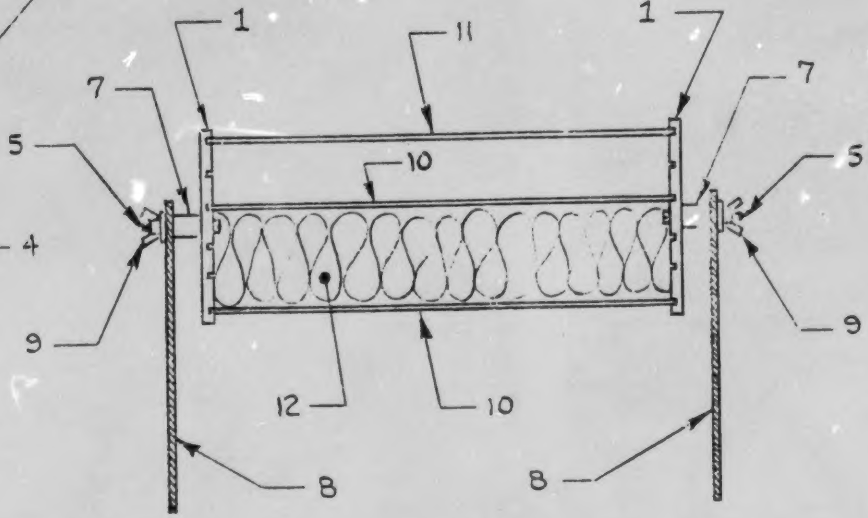

20°
0°
5°
10°
15°
20°
25°
30°
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
85°
90° W
95°
100°
105°
5°
10°
15°
20°
25°
30°
35°
40°
45°
50°
55°
60°
65°
70°
75°
80°
85°
90° E
95°
100°
105°
25°
30°
35°
40°
50°
S
DWG. NO. L-3
SH. 2 of 3

L-3-2


NORTH
WEST
SOUTH
EAST
NORTH
ALTITUDE (DEGREES)
AZIMUTH (DEGREES)
DWG. NO. L-3
SH. 3 OF 3

FLAT PLATE COLLECTOR


1
1
11
3
SEE DETAIL 1
4
9
1
1
8

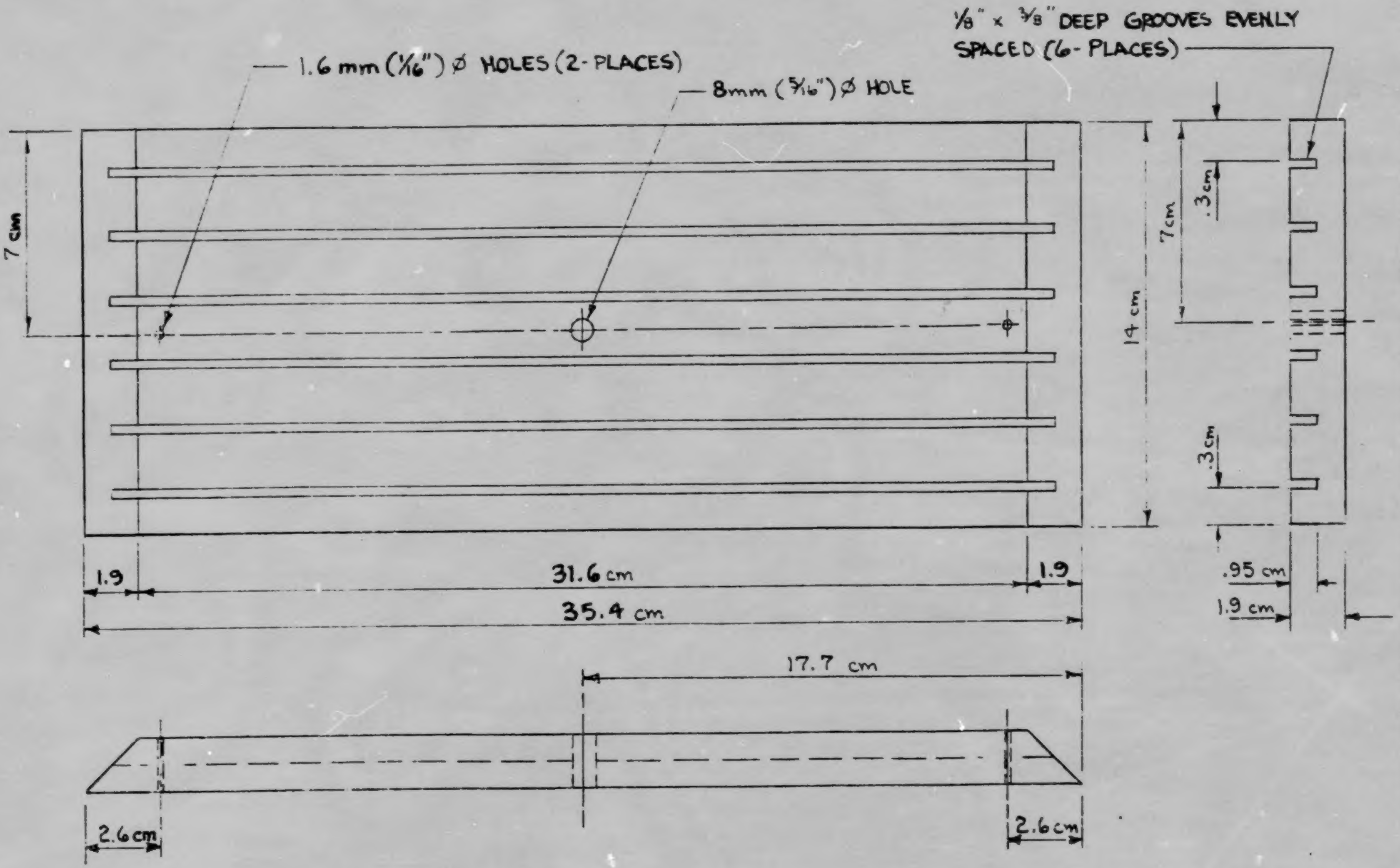

1
11
1
7
7
5
10
5
9
9
12
10
8
8

SEE DETAIL 2 ALSO

TRANSPARENCY: COLLECTORS AND ENERGY STORAGE YL-195

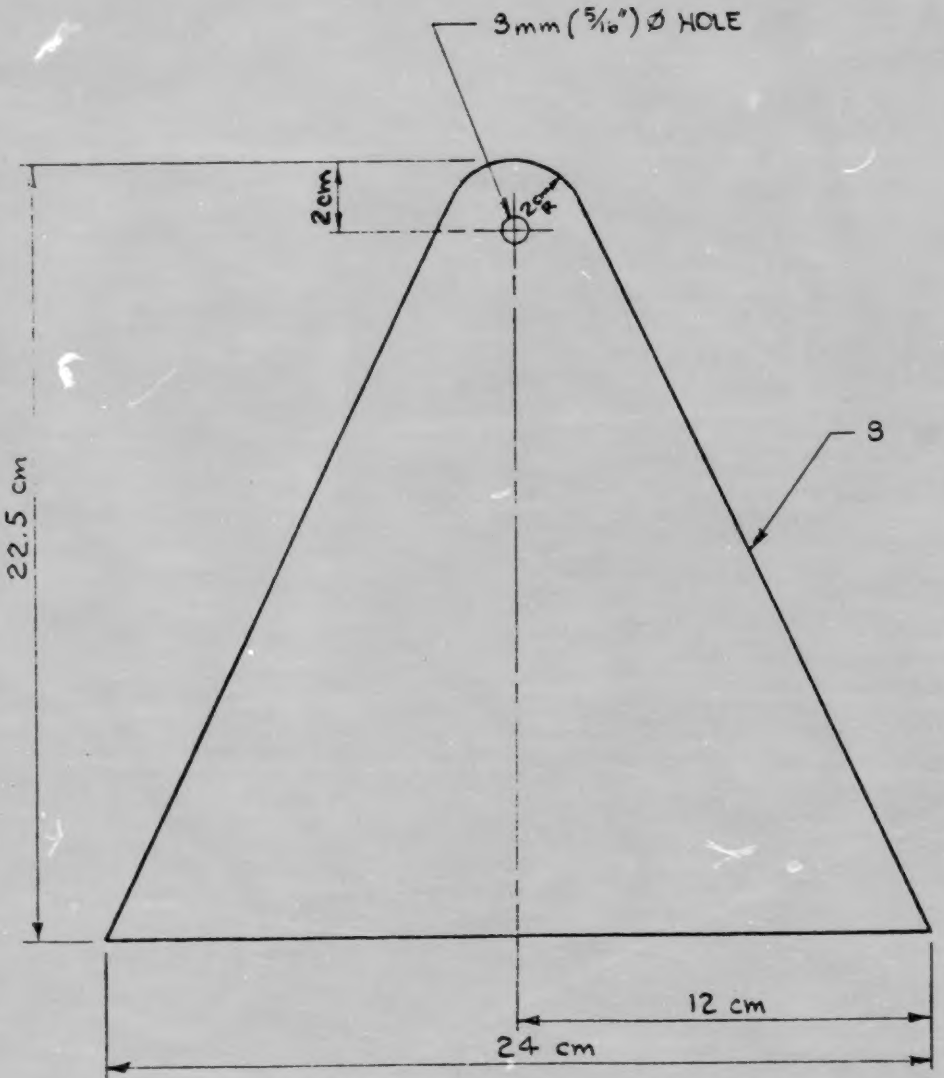
L-2-1

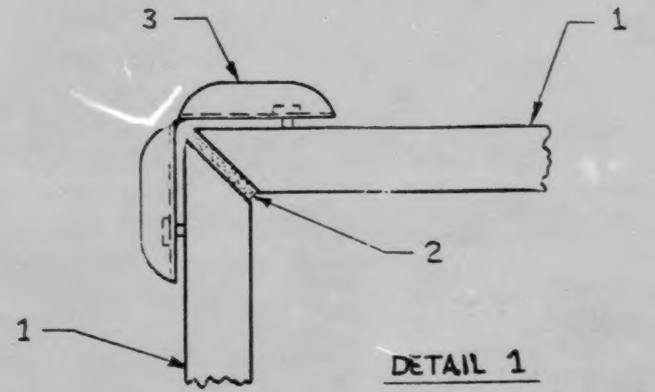
NAVARRO COLLEGE, SOLAR ENERGY DIV.		ASSEMBLY		DWG. NO. L-2
SCALE : NONE	DATE : 11-13-79	DR. BY : CM	CK. BY : HAC	SH. 1 OF 6


1/8" × 3/8" DEEP GROOVES EVENLY SPACED (6- PLACES)
1.6 mm (1/16") Ø HOLES (2-PLACES)
8mm (5/16") Ø HOLE
7 cm
14 cm
7cm
.3cm
.3cm
1.9
31.6 cm
1.9
35.4 cm
.95 cm
1.9 cm
17.7 cm
2.6cm
2.6cm

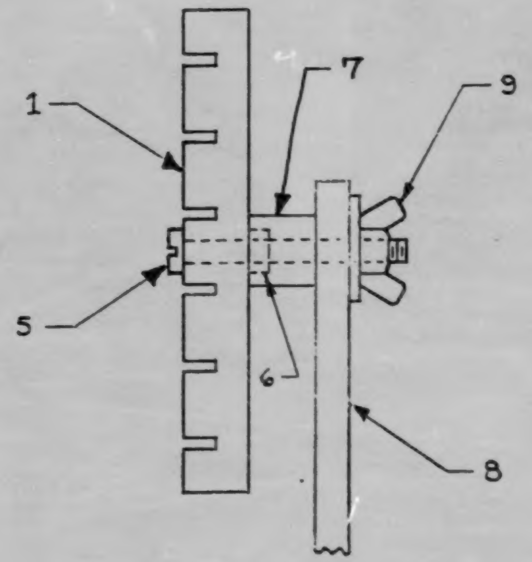
NAVARRO COLLEGE, SOLAR ENERGY DIV.		PART NO. 1		DWG. NO. L-2
SCALE : NONE	DATE : 11-5-79	DR. BY : CM	CK. BY : HAB	SH. 2 OF 6

L-2-2


3mm (5/16") Ø HOLE
2cm
2cm
22.5 cm
8
12 cm
24 cm



DETAIL 1



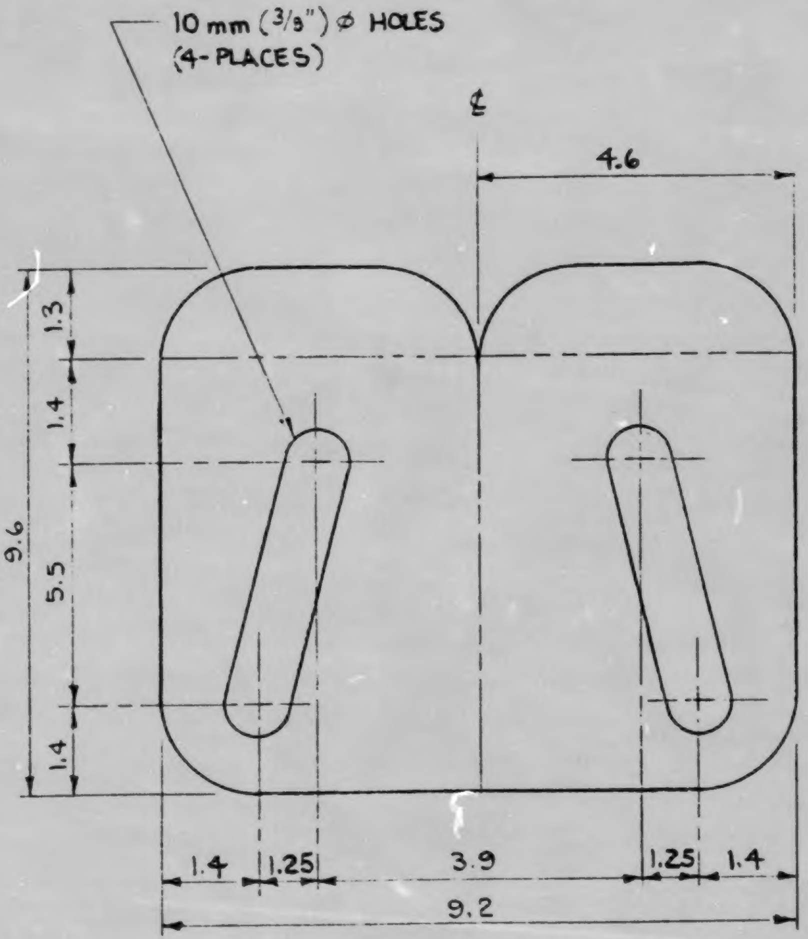
DETAIL 2

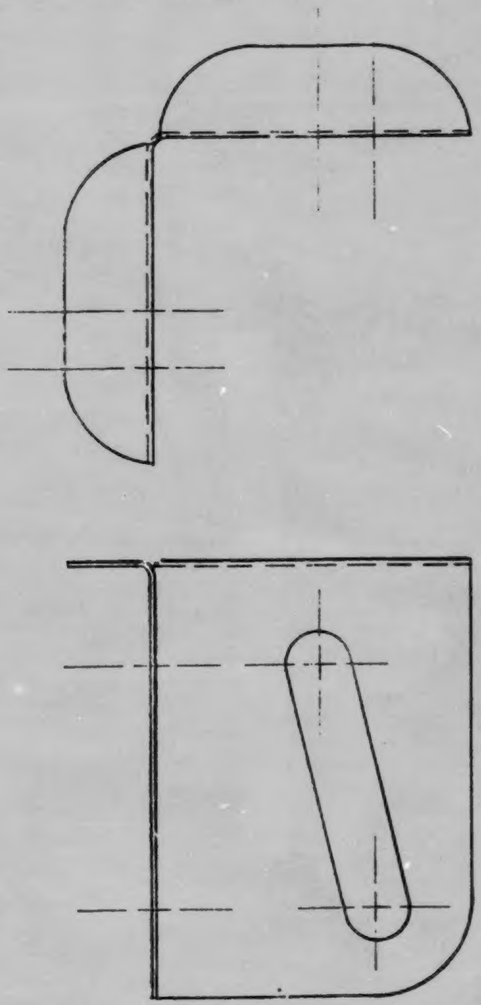
NAVARRO COLLEGE, SOLAR ENERGY DIV.		PART 8 / DETAILS 1 & 2	DWG. NO. L-2
SCALE: NONE	DATE: 11-8-79	DR. BY: CM	CK. BY: HAB	SH. 3 OF 6

TRANSPARENCY: COLLECTORS AND ENERGY STORAGE VI-199

ROUND OFF ALL CORNERS

10 mm (3/8") ⌀ HOLES
(4-PLACES)

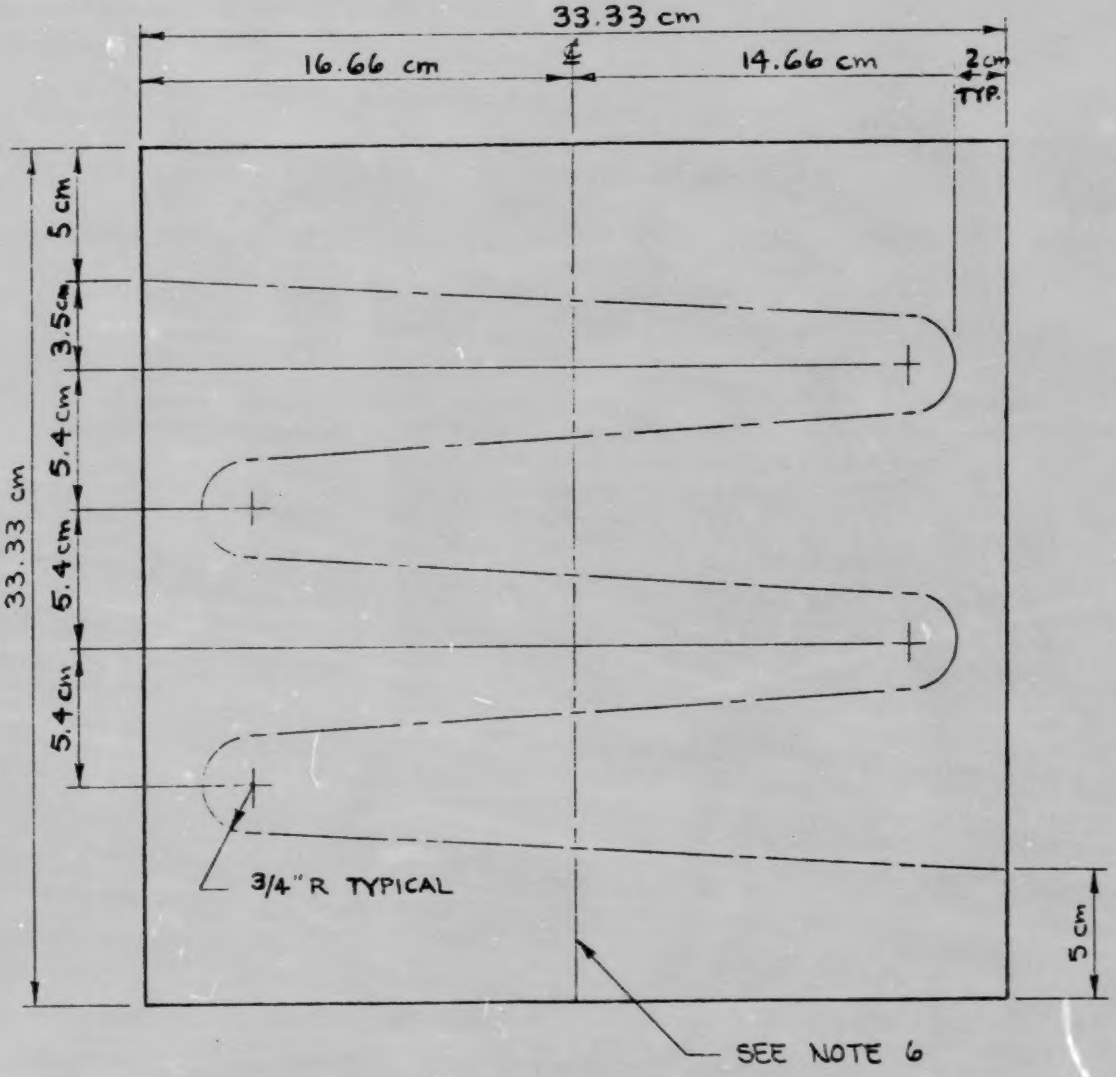

℄
4.6
1.3
1.4
9.6
5.5
1.4
1.4
1.25
3.9
1.25
1.4
9.2



ALL DIMENSIONS IN CENTIMETERS

L-2-4

NAVARRO COLLEGE, SOLAR ENERGY DIV.
PART 3
DWG. NO. L-2
SCALE: NONE
DATE: 11-7-79
DR. BY: CM
CK. BY: HAB
SH. 4 OF 6


33.33 cm
16.66 cm
℄
14.66 cm
2 cm
TYP.
5 cm
3.5 cm
5.4 cm
5.4 cm
5.4 cm
33.33 cm
3/4" R TYPICAL
5 cm
SEE NOTE 6

NOTES

1. TUBING OPTIONAL.
2. DRILL ADDITIONAL HOLES IN PART #1 AS NEEDED.
3. TUBING TO EXTEND BEYOND BOX MIN. 3.3 cm (1½").
4. TUBING FOR SERPENTINE PATTERN APPROX. 168 cm LONG.
5. TUBING TO BE ATTACHED W/ 95-5 SOLDER ALONG ENTIRE LENGTH.
6. STRAIGHT TUBE TO BE ATTACHED TO SEPARATE ABSORBER TO TEST EFFECT OF FIN WIDTH.

NAVARRO COLLEGE, SOLAR ENERGY DIV.		PART 10 : OPTIONAL ABSORBERS		DWG. NO. L-2
SCALE: NONE	DATE: 11-14-79	DR. BY: CM	CK. BY: HAB	SH. 5 OF 6

PARTS & MATERIALS LIST

PART NO.	NAME & DESCRIPTION	REQ'D / UNIT
1	SIDE 3/4" BIRCH PLYWOOD	4
2	SEAL STRIP ADHESIVE-BACKED FOAM WEATHERSTRIP 1.9cm WIDE	4
3	CORNER CLAMP 24 GA. GALVANIZED STEEL	4
4	SCREW #6 RH WOOD SCREW, 3/4" LONG	8
5	BOLT 1/4"-20 RH MACHINE BOLT, 3" LONG	2
6	NUT 1/4"-20	2
7	SPACER 3/4"ø PIPE, 2 cm LONG	2
8	BASE 1/4" OR 3/8" PLYWOOD	2
9	WASHER & WING NUT 1/4"-20	2 EA.
10	ABSORBER PLATE SEE NOTES BELOW	MIN. 2
11	GLAZING 33.33 cm x 33.33 cm (13 1/8" x 13 1/8") VARIETY OF TYPES	MIN. 1
12	INSULATION VARIOUS THICKNESSES & TYPES	
[1] 13	TUBING 1/4" O.D. x 168 cm LONG, COPPER	1
	PAINT GOOD QUALITY HIGH-TEMPERATURE	

NOTES

1. A VARIETY OF COATINGS SHOULD BE USED ON ABSORBER PLATES TO ALLOW TESTING OF ALTERNATIVES.
2. ONE ABSORBER PLATE IS USED AS BACK OF COLLECTOR.
3. GROOVES IN PART #1 ALLOW VARIATIONS IN COLLECTOR GEOMETRY.
4. ABSORBER PLATES SHOULD BE MADE OF A VARIETY OF MATERIALS & THICKNESSES TO ALLOW TESTING OF ALTERNATIVES. ABSORBER SIZE IS 33.33 cm x 33.33 cm.

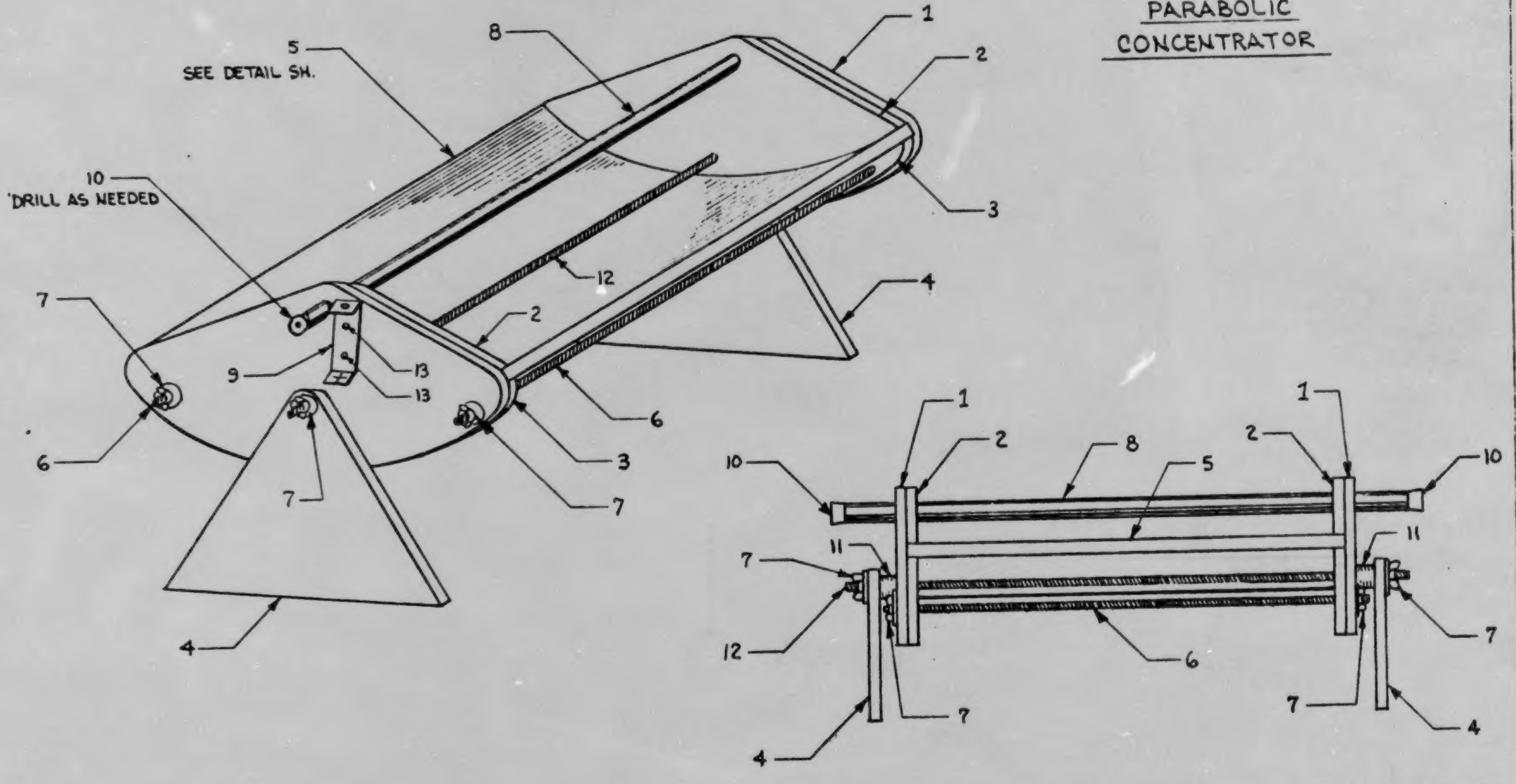
REVISIONS ; [1] COPPER TUBING 7-14-30

NAVARRO COLLEGE, SOLAR ENERGY DIV.		PARTS & MATERIALS LIST	DWG. NO. L-2
SCALE : NONE	DATE : 11-13-79	DR. BY : CML	CK. BY : HAB	SH. 6 OF 6

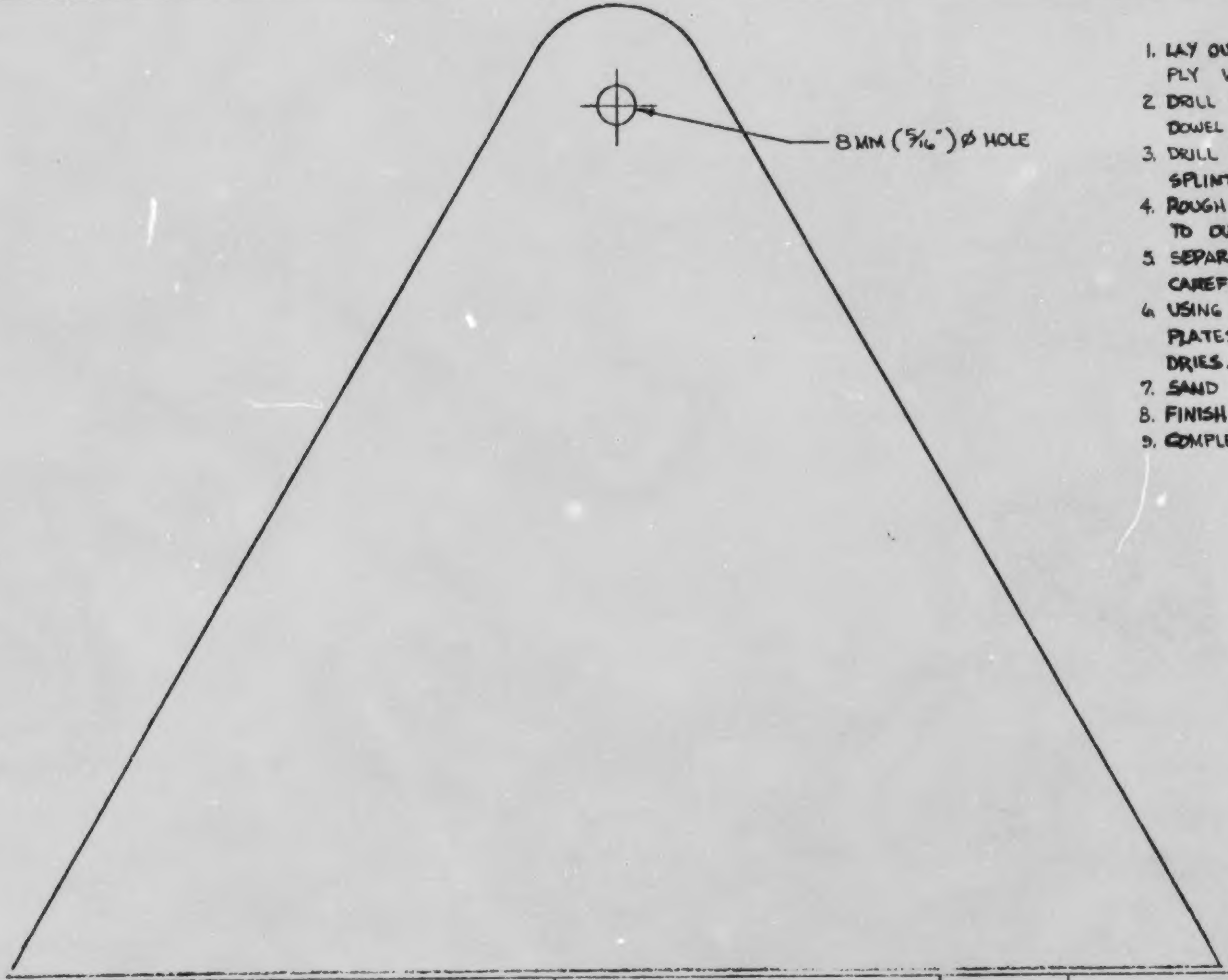
TRANSPARENCY: COLLECTORS AND ENERGY STORAGE VI-205

L-2-6

PARABOLIC CONCENTRATOR


5
SEE DETAIL SH.
8
1
2
3
10
'DRILL AS NEEDED
12
4
7
2
9
13
13
6
3
7
6
7
4
1
2
8
5
1
2
10
10
11
11
7
7
12
6
7
7
4
4

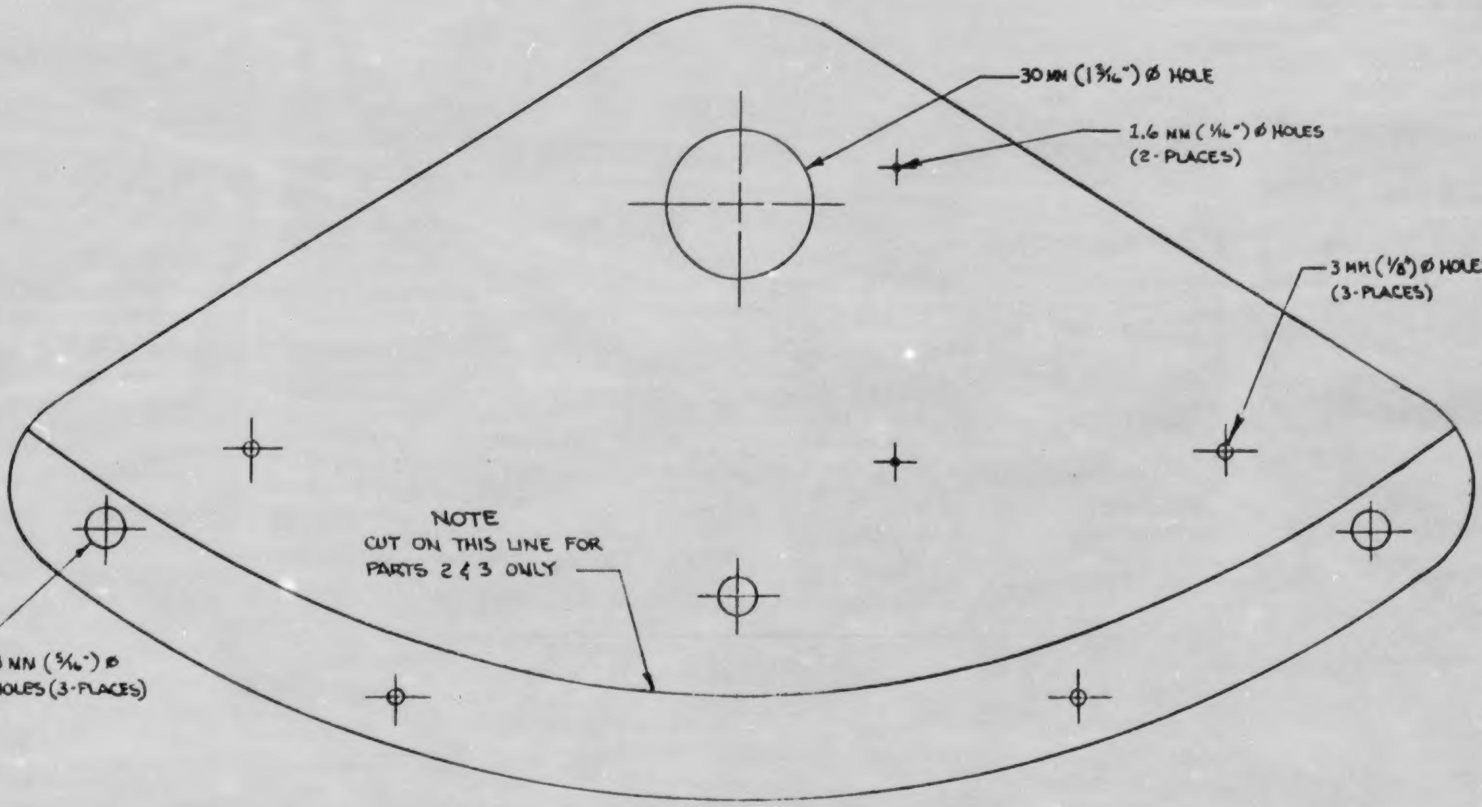
DR.BY: CM	CK.BY:	NAVARRO COLLEGE	ASSEMBLY	9-5-79	SCALE: NONE	DWG.NO. L-1	SH. 1 OF 4



CONSTRUCTION NOTES

1. LAY OUT TWO END PLATES ON A SHEET OF PLY W/A SECOND SHEET UNDERNEATH.
2. DRILL 1/8" Ø DOWEL HOLES, INSERTING 1/8" Ø DOWEL AFTER DRILLING EACH HOLE.
3. DRILL ALL OTHER HOLES – CAREFULLY, DO NOT SPLINTER WOOD.
4. ROUGH CUT W/ BAND SAW OR COPING SAW TO OUTSIDE LINES.
5. SEPARATE DOWELED END PLATES & CAREFULLY SAW ON PARABOLIC LINE.
6. USING DOWELS & GLUE REASSEMBLE END PLATES. — CLAMP OR WEIGHT UNTIL GLUE DRIES.
7. SAND TO OUTSIDE LINES.
8. FINISH W/APPROPRIATE OUTDOOR COATING.
9. COMPLETE ASSEMBLY – SEE SH. 1.

DR. BY: CM	CK. BY:	NAVARRO COLLEGE	BASE PART 4	9-4-79	SCALE: FULL SIZE	DWG. NO. L-1	SH. 2 OF 4

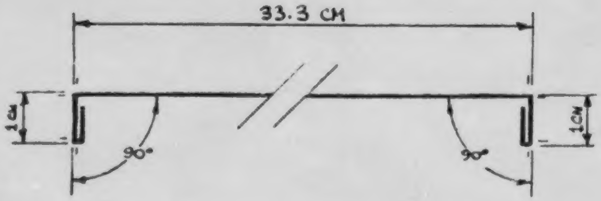

30 MM (1 3/16") Ø HOLE
1.6 MM (1/16") Ø HOLES (2-PLACES)
3 MM (1/8") Ø HOLES (3-PLACES)
NOTE
CUT ON THIS LINE FOR PARTS 2 & 3 ONLY
8 MM (5/16") Ø HOLES (3-PLACES)

DR.BY: CM	CK.BY:	NAVARRO COLLEGE	END PLATE PARTS 1, 2 & 3	5-4-79	SCALE: FULL SIZE	DWG.NO. L-1	SH. 3 OF 4

REVISION ① 11-13-79 CM

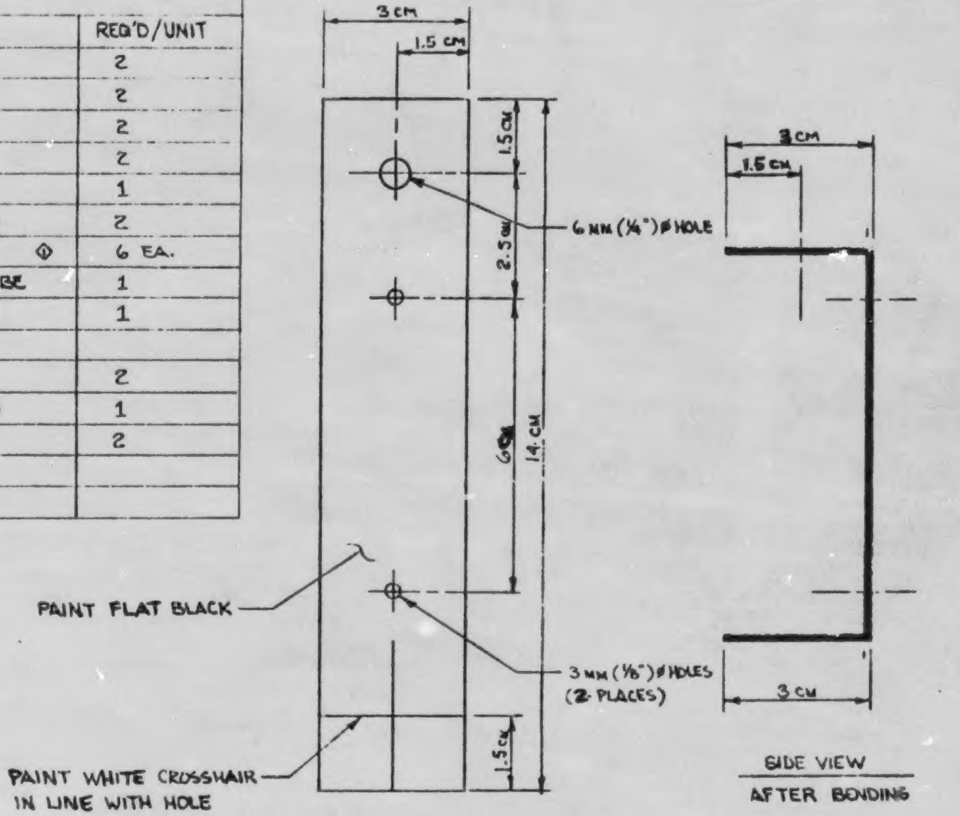
PARTS LIST

PART NO.	NAME & MAT'L	REQ'D/UNIT
1	END PLATE 1/4" OR 3/8" PLYWOOD	2
2	REFLECTOR HOLDER 1/4" OR 3/8" PLYWOOD	2
3	—— " —— " —— "—"—" —— " ——	2
4	BASE 1/4" OR 3/8" PLYWOOD	2
5	REFLECTOR 37.3 CM × OPTIONAL "X" LONG	1
6	TIE ROD 1/4"Ø × ("X"+4) CM LONG ALL THREAD ROD	2
7	WASHER & WING NUT 1/4" ①	6 EA.
8	FLUID LINE 1 1/8"Ø × ("X"+4) CM LONG COPPER TUBE	1
9	SUN LOCATOR 22 GA. GALVANIZED STEEL	1
10	PLUG	
11	SPACER	2
12	TIE ROD 1/4"Ø × ("X"+10) CM LONG ALL THREAD ROD	1
13	SCREW #5 RH WOOD SCREW	2


33.3 CM
1 CM
1 CM
90°
90°

DETAIL OF REFLECTOR EDGES

BEND AS SHOWN

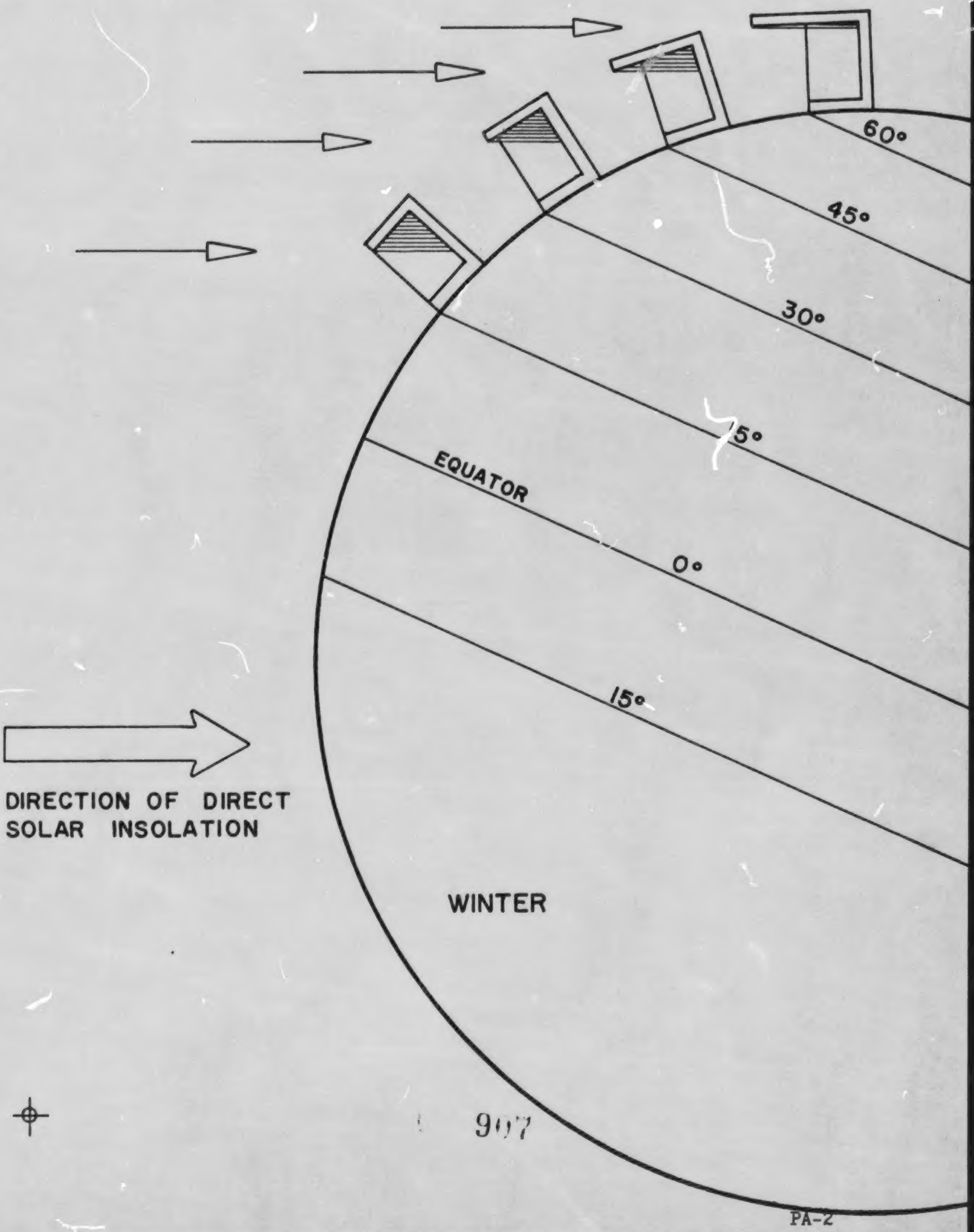

3 CM
1.5 CM
1.5 CM
2.5 CM
6 CM
14 CM
1.5 CM
6 MM (1/4")Ø HOLE
3 MM (1/8")Ø HOLES
(2 PLACES)
PAINT FLAT BLACK
PAINT WHITE CROSSHAIR
IN LINE WITH HOLE
3 CM
1.5 CM
3 CM

SIDE VIEW

AFTER BENDING

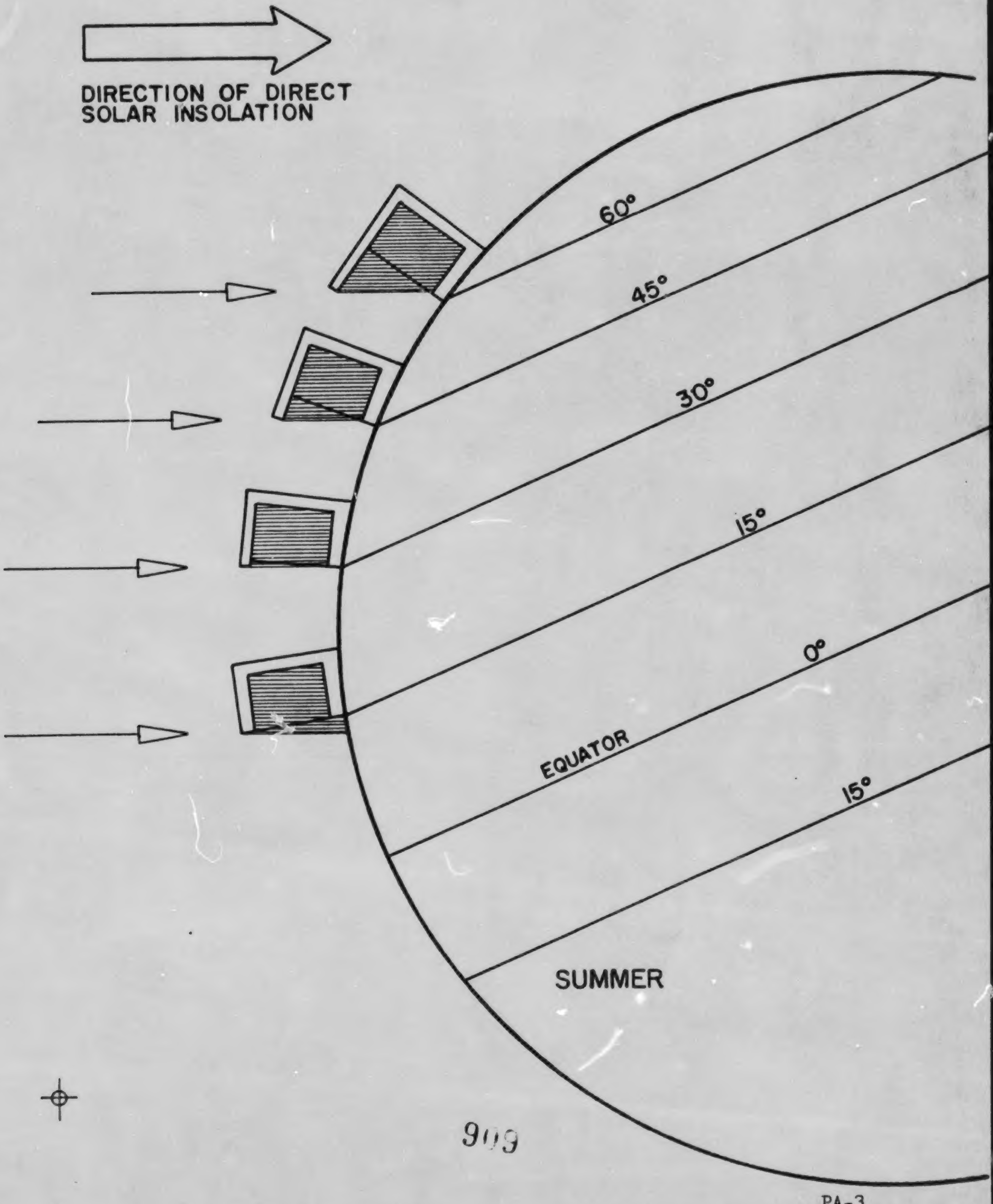
SUN LOCATOR

DR. BY: CM	CK. BY:	NAVARRO COLLEGE	PARTS LIST / PARTS 5 & 9	9-5-79	SCALE: FULL SIZE	DWG. NO. L-1	SH. 4 OF 4


60°
45°
30°
15°
EQUATOR
0°
15°
DIRECTION OF DIRECT SOLAR INSOLATION
WINTER

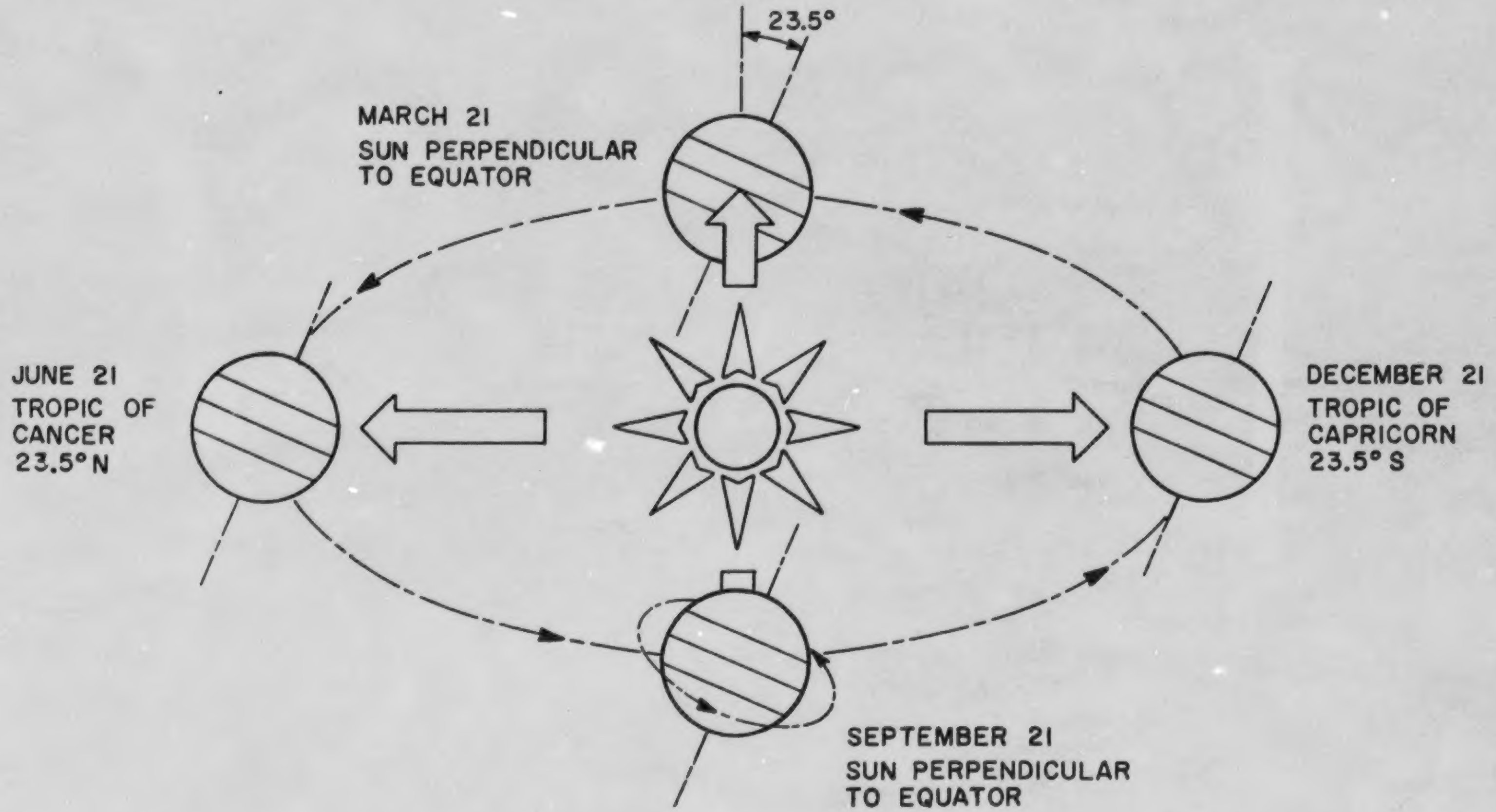
SOUTHERN HEMISPHERE SUMMER

DURING NORTHERN HEMISPHERE WINTER


DIRECTION OF DIRECT SOLAR INSOLATION
60°
45°
30°
15°
0°
EQUATOR
15°
SUMMER

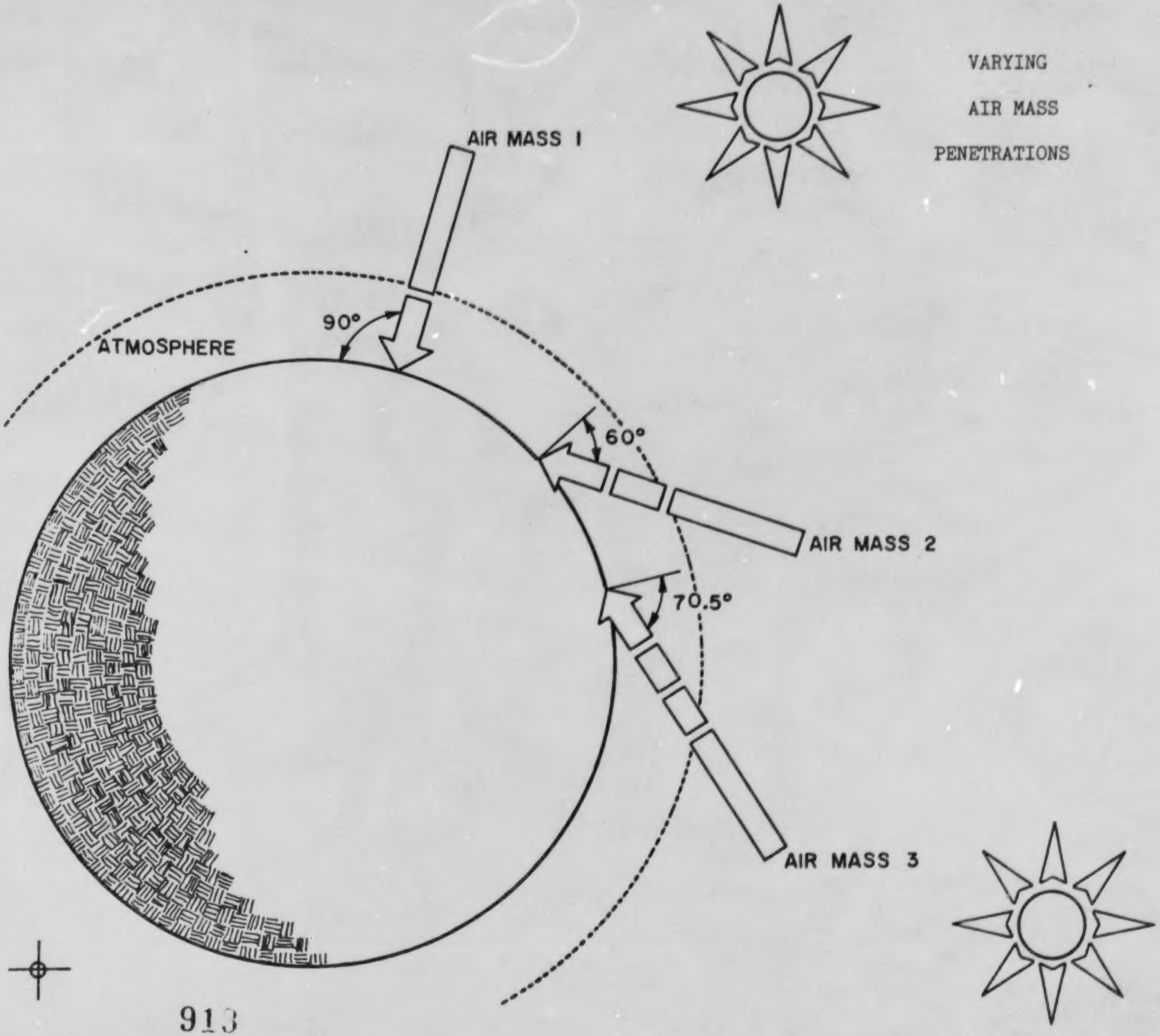
SOUTHERN HEMISPHERE WINTER

EARTH TILT DUE TO SEASONAL VARIATIONS


23.5°
MARCH 21
SUN PERPENDICULAR
TO EQUATOR
JUNE 21
TROPIC OF
CANCER
23.5°N
DECEMBER 21
TROPIC OF
CAPRICORN
23.5° S
SEPTEMBER 21
SUN PERPENDICULAR
TO EQUATOR

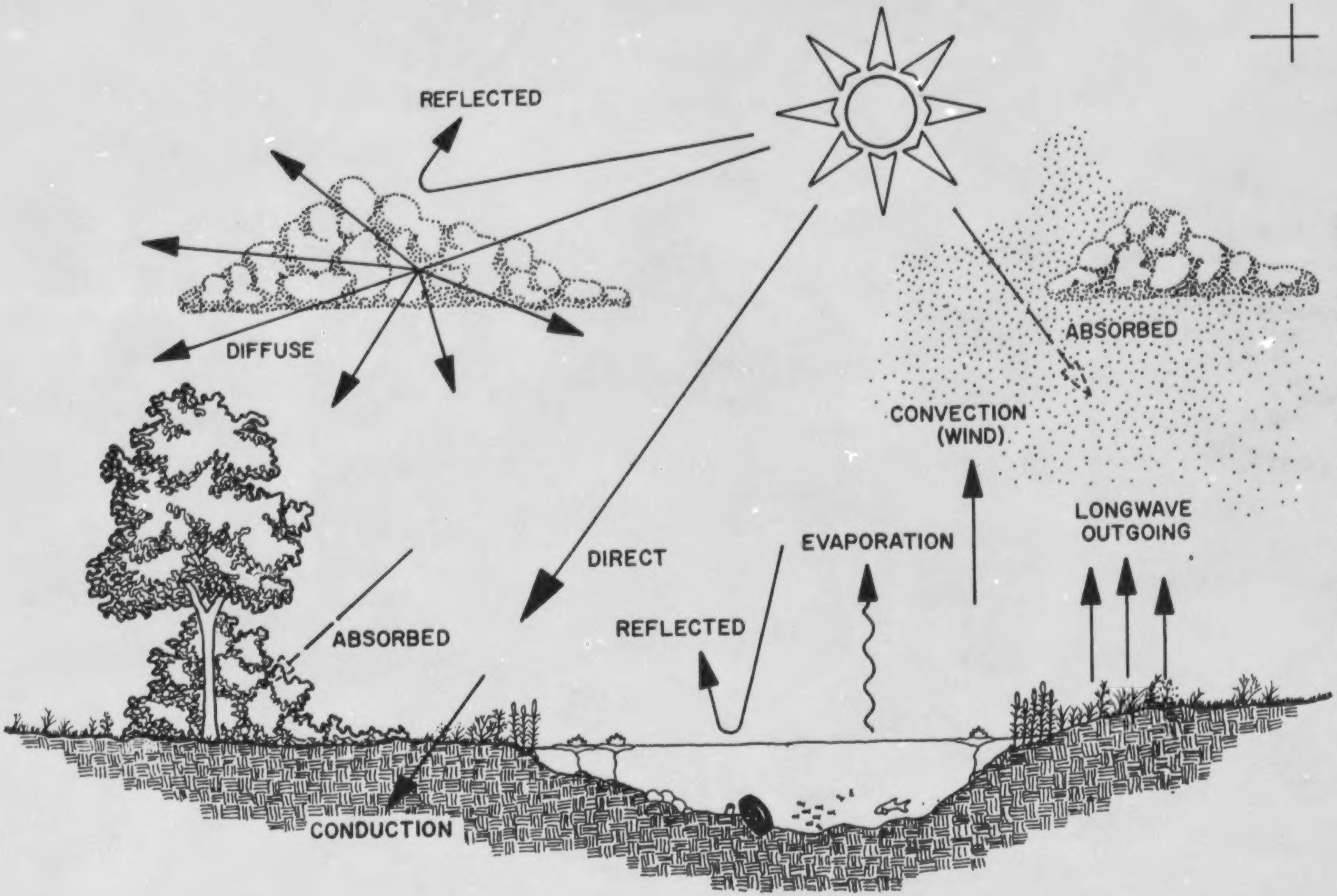
SR-2

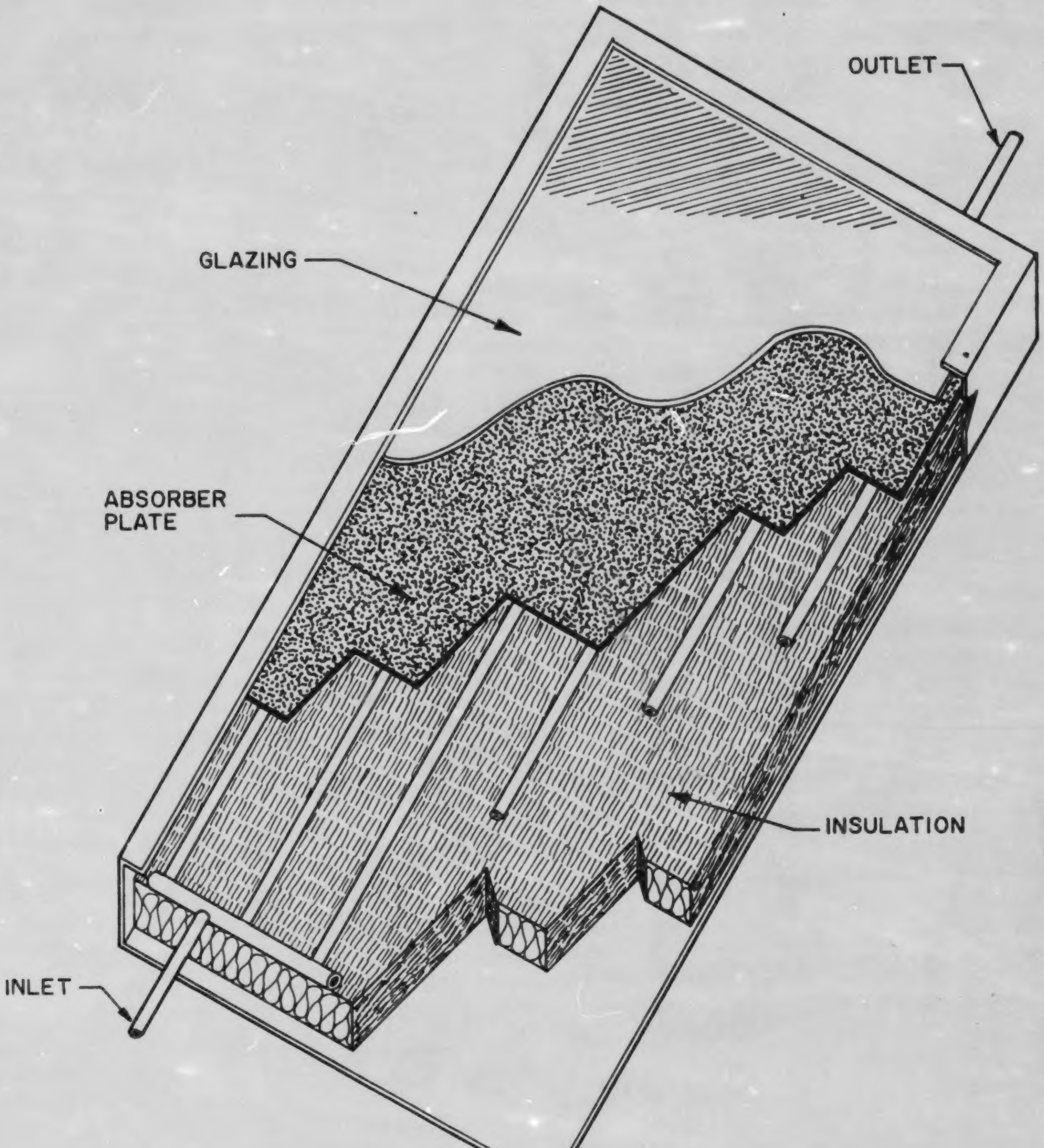
VARYING AIR MASS PENETRATIONS


AIR MASS 1
90°
ATMOSPHERE
60°
AIR MASS 2
70.5°
AIR MASS 3

SR-3

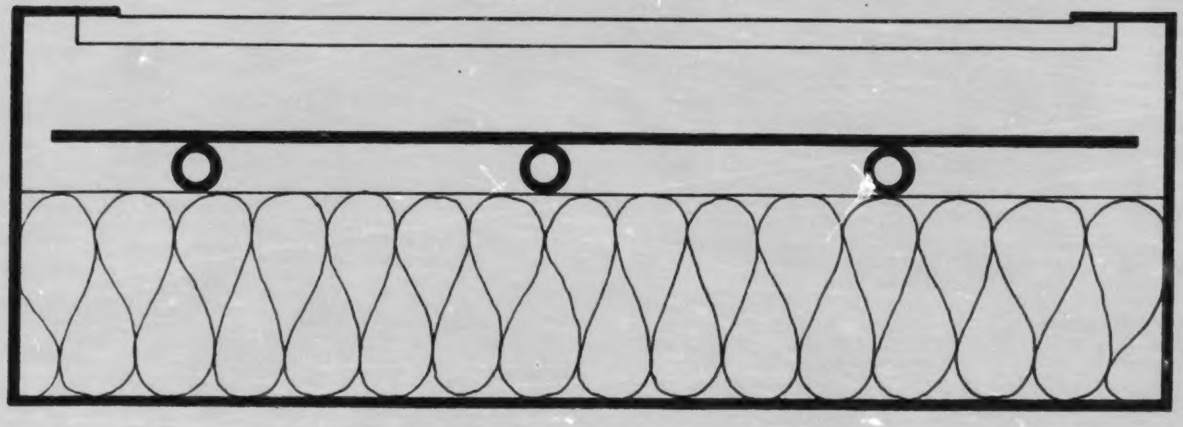
TRANSPARENCY: COLLECTORS AND ENERGY STORAGE


REFLECTED
DIFFUSE
ABSORBED
CONVECTION (WIND)
LONGWAVE OUTGOING
EVAPORATION
DIRECT
REFLECTED
ABSORBED
CONDUCTION


OUTLET
GLAZING
ABSORBER PLATE
INSULATION
INLET

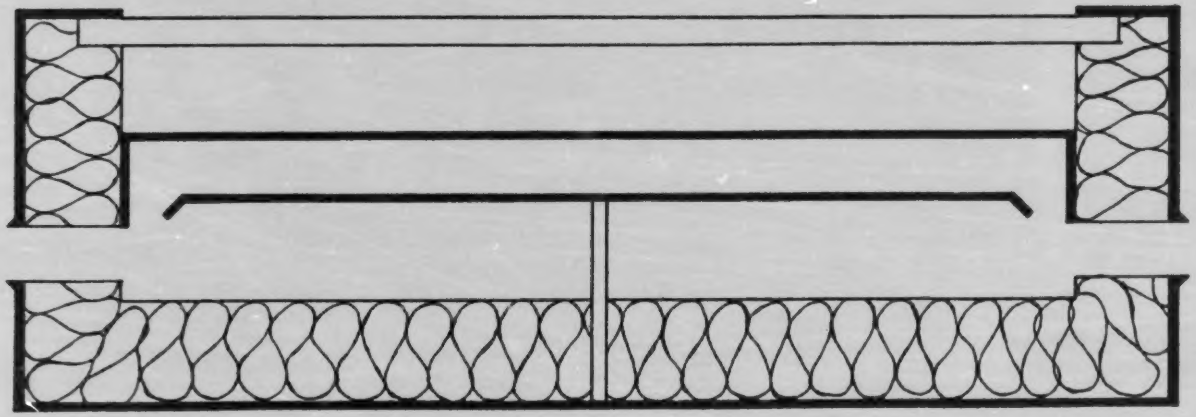
CUT-AWAY OF LIQUID FLAT PLATE COLLECTOR

CROSS-SECTION OF LIQUID FLAT PLATE COLLECTOR



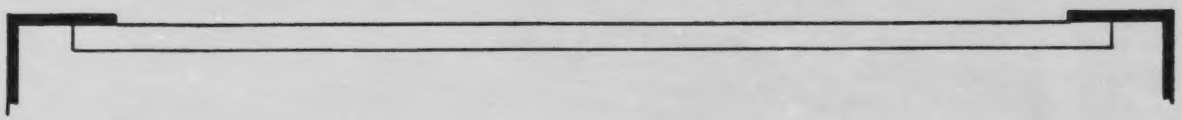
FP-2

CROSS-SECTION OF AIR FLAT PLATE COLLECTOR



FP-3

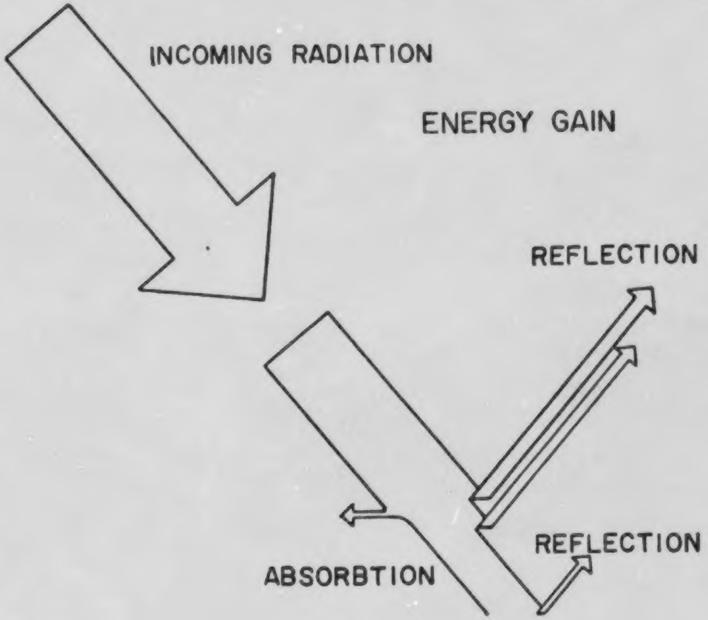
FLAT PLATE COLLECTOR GLAZING



ELEMENTS OF FLAT PLATE COLLECTOR CONSTRUCTION

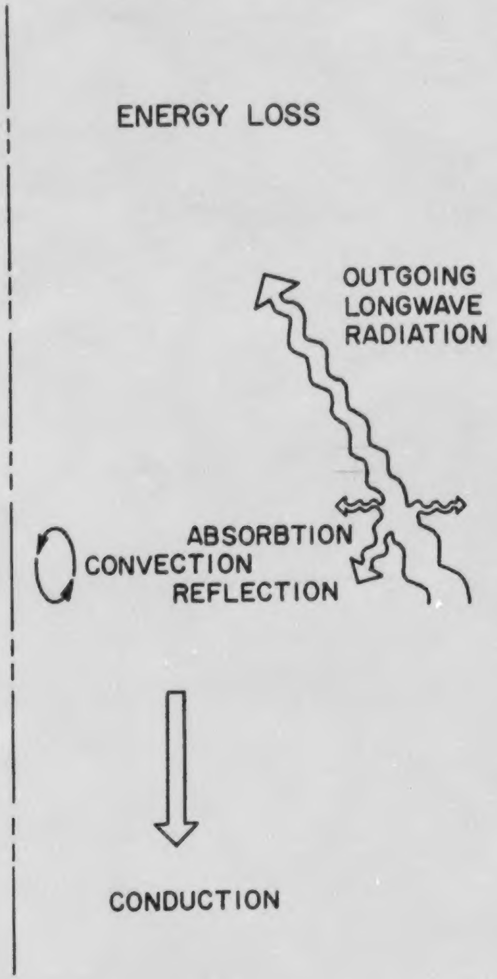
ABSORBER PLATE
GLAZING
FLUID PASSAGES
INSULATION
HOUSING

EFFECT OF GLAZING ON INCOMING RADIATION

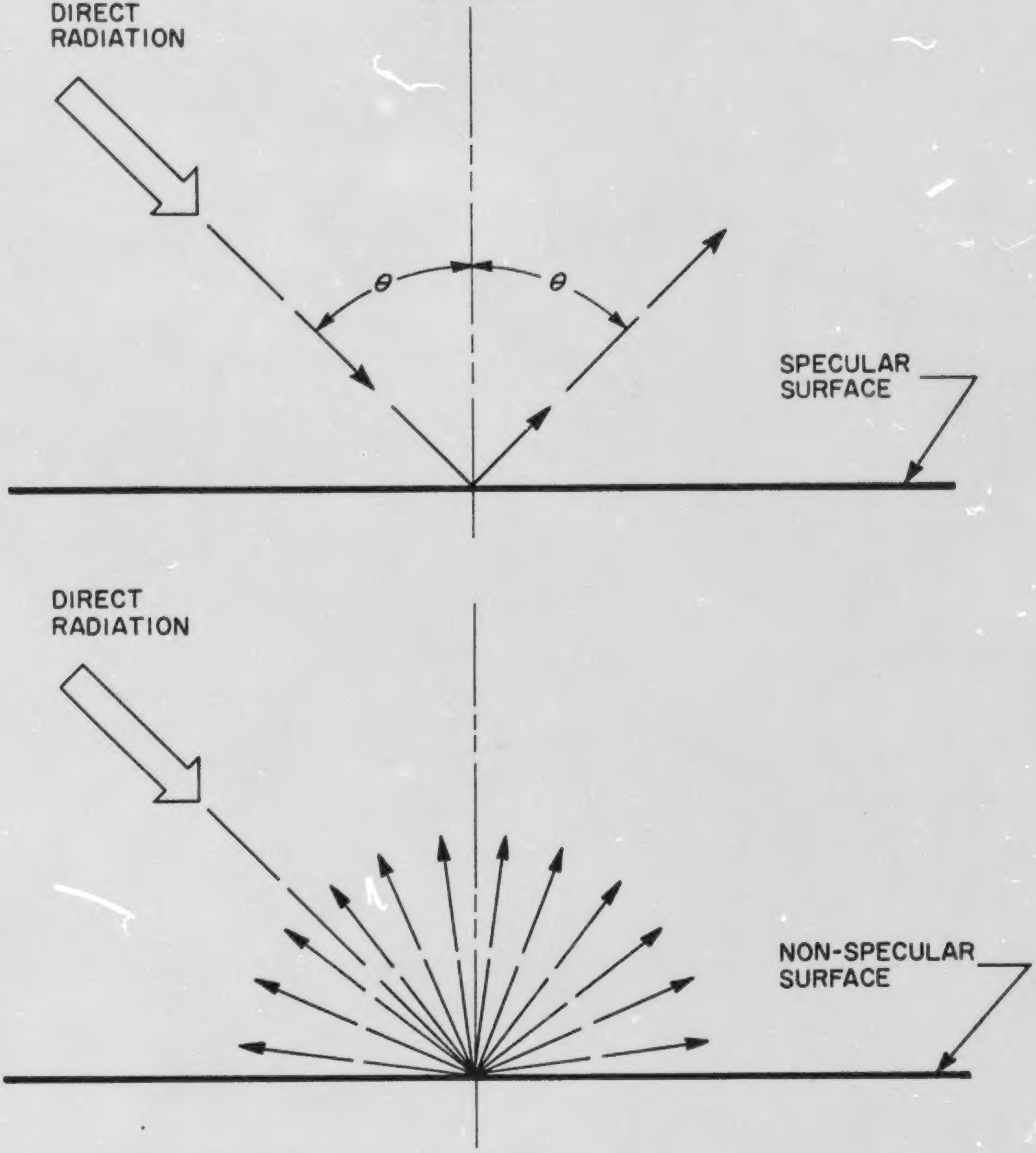

INCOMING RADIATION
ENERGY GAIN
REFLECTION
REFLECTION
ABSORBTION

TRANSPARENCY: COLLECTORS AND ENERGY STORAGE

ENERGY FLOW RESULTING FROM COLLECTOR-TRAPPED RADIATION

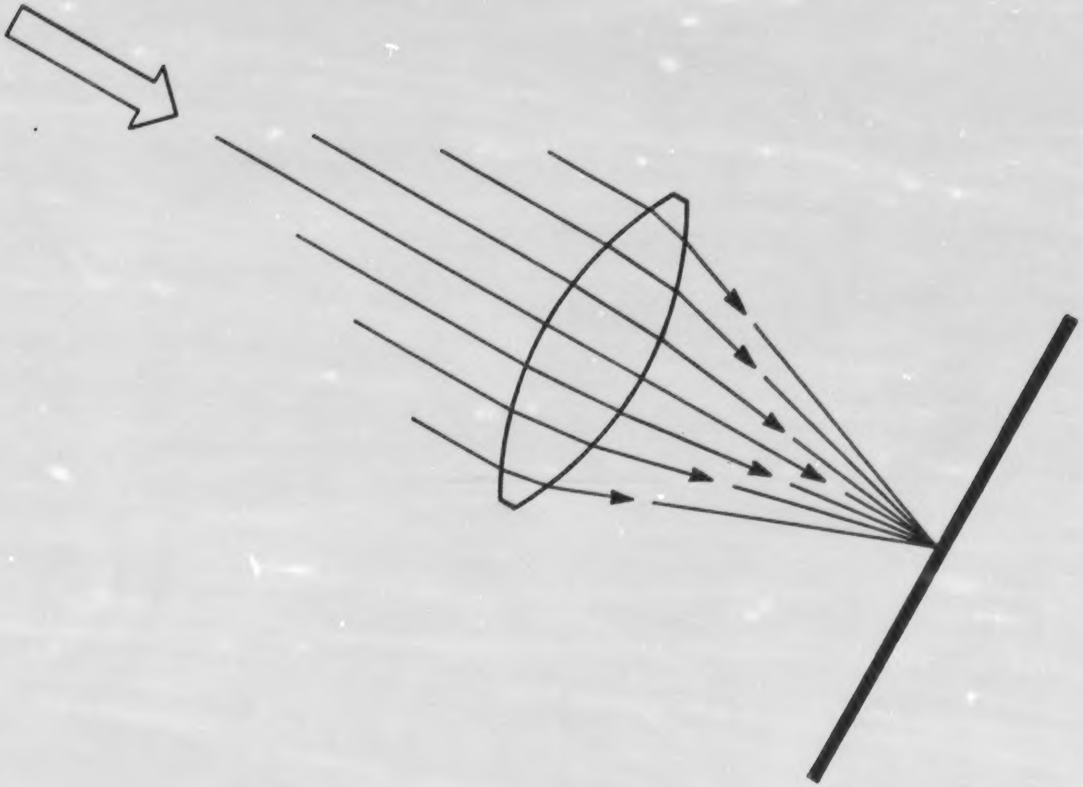

ENERGY LOSS
OUTGOING
LONGWAVE
RADIATION
ABSORBTION
CONVECTION
REFLECTION
CONDUCTION

FP-2, 3-D


NORMAL
DIRECT RADIATION
θ
θ
SPECULAR SURFACE
DIRECT RADIATION
NON-SPECULAR SURFACE

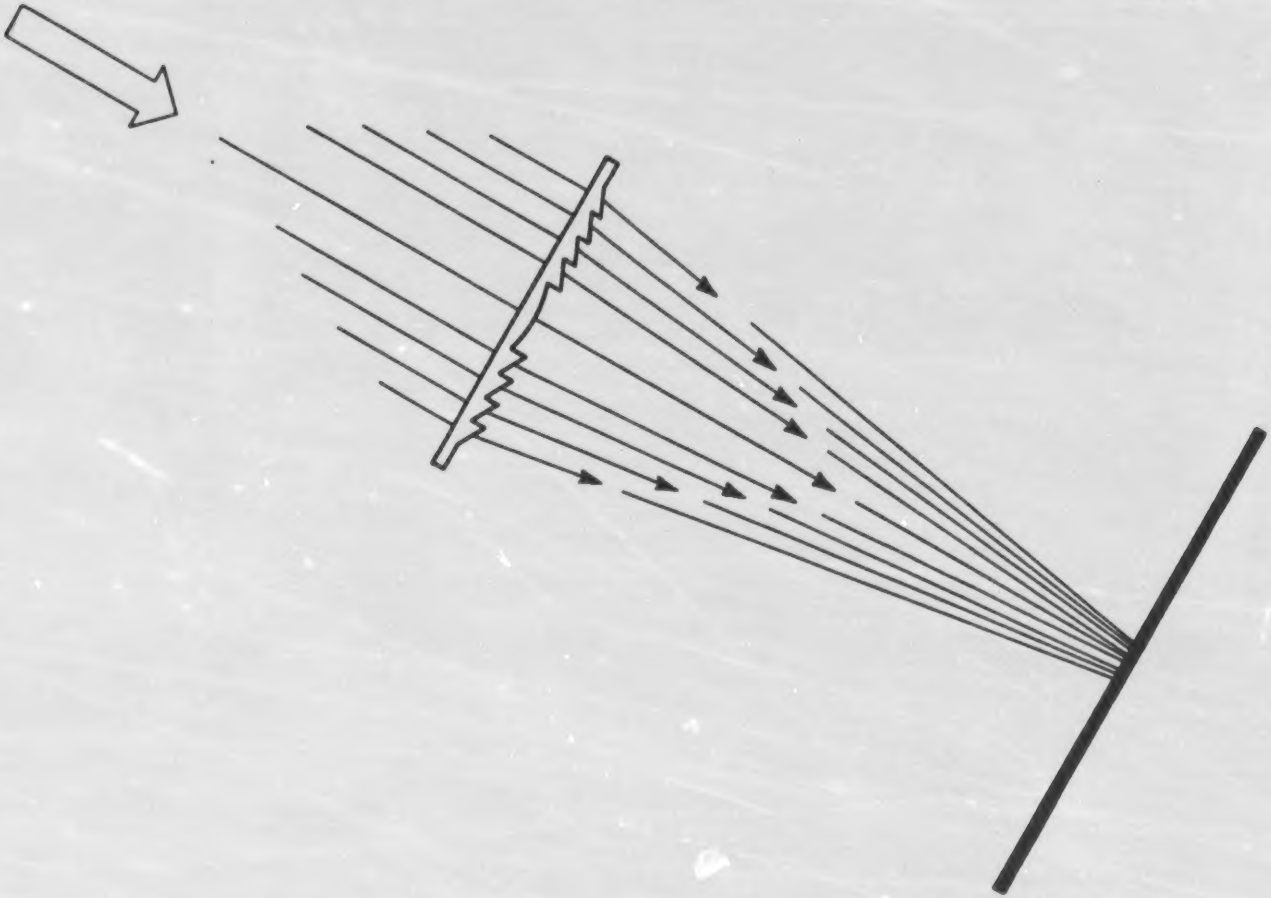
REFLECTIVE EFFECTS OF TWO TYPES OF SURFACES

LIGHT CONCENTRATION FROM CONVEX LENS

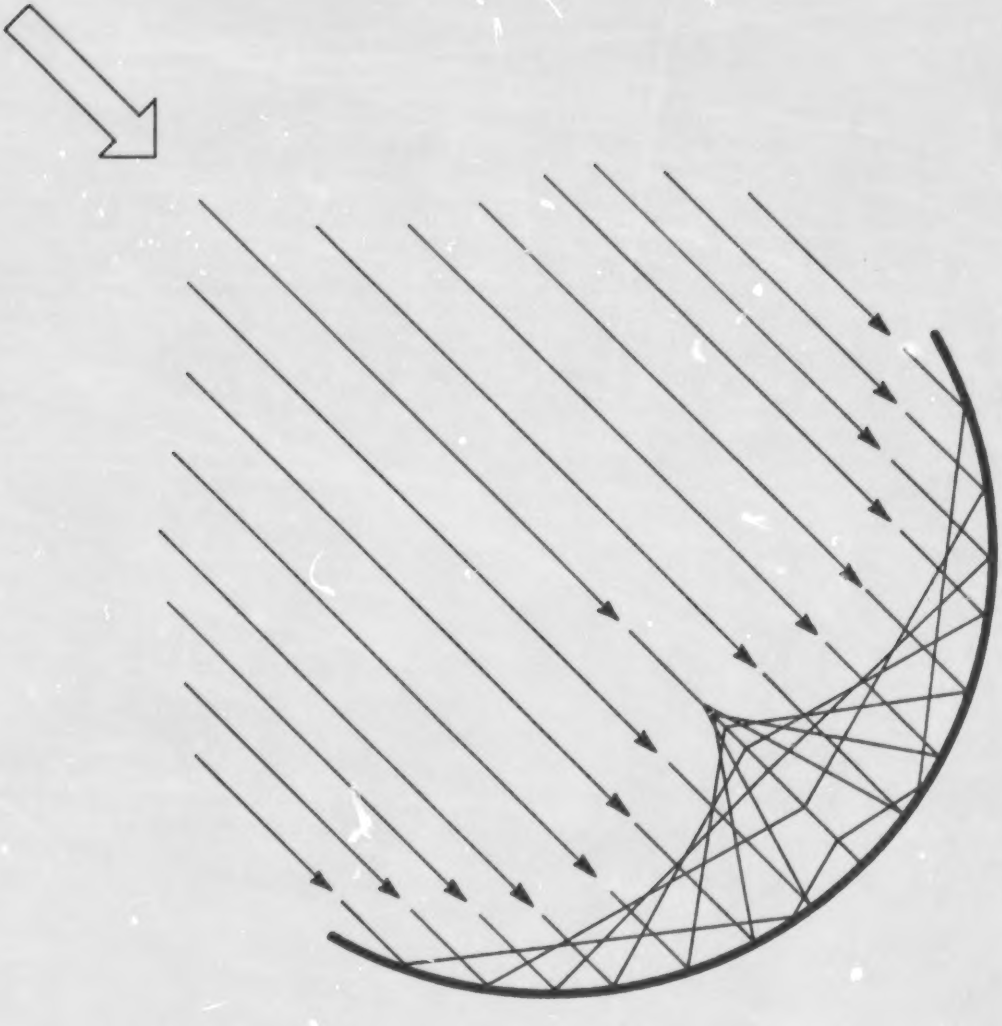


931

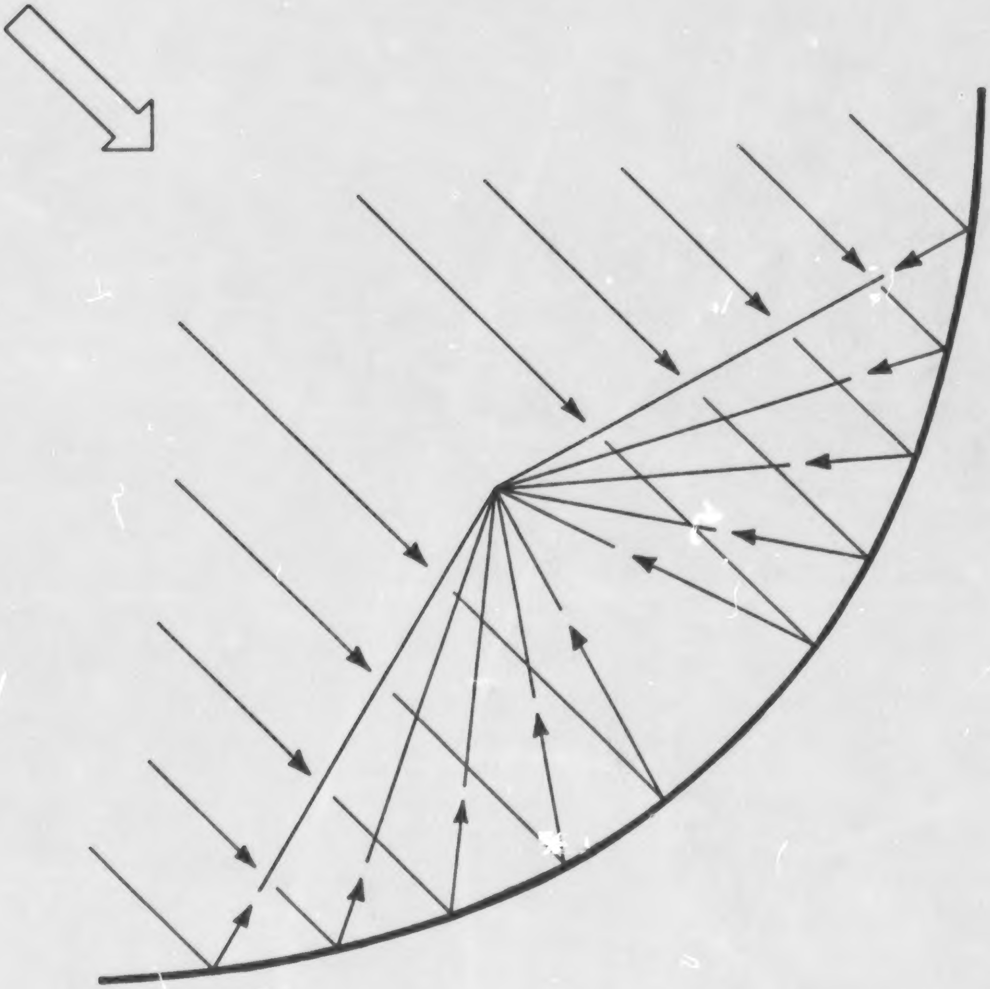
LIGHT CONCENTRATION FROM RESNEL LENS



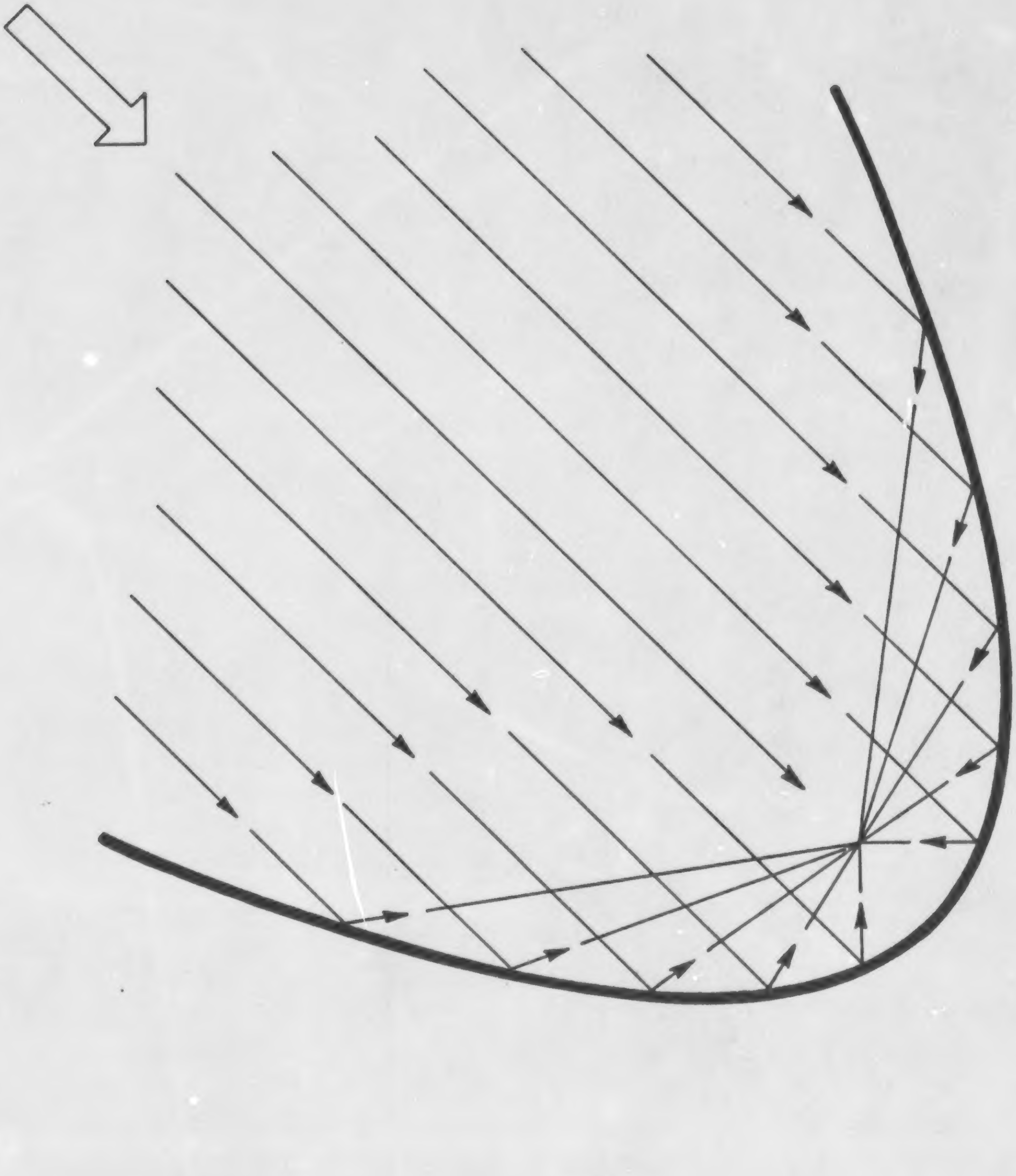
CONCENTRATION EFFECTS OF CIRCULAR MIRROR



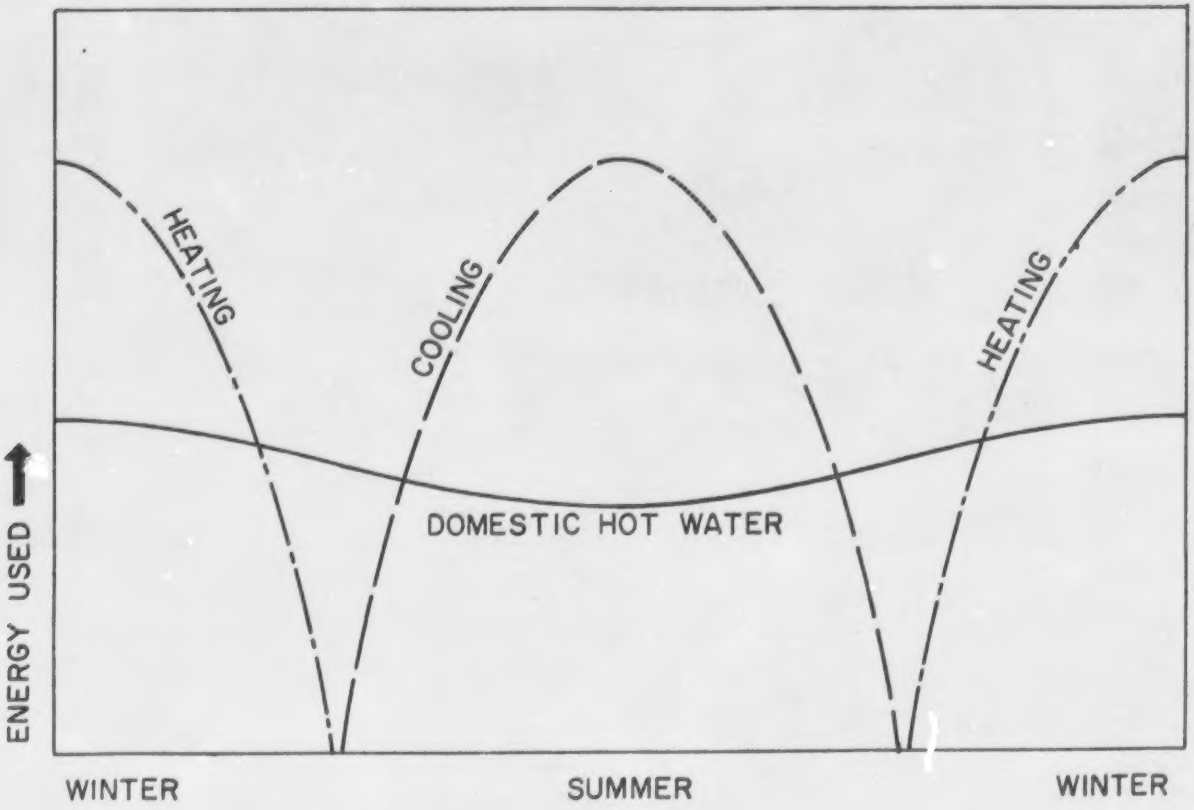
CONCENTRATION EFFECT OF PARABOLA



CONCENTRATION EFFECT FROM COMPUND PARABOLIC CONCENTRATOR (CPC)



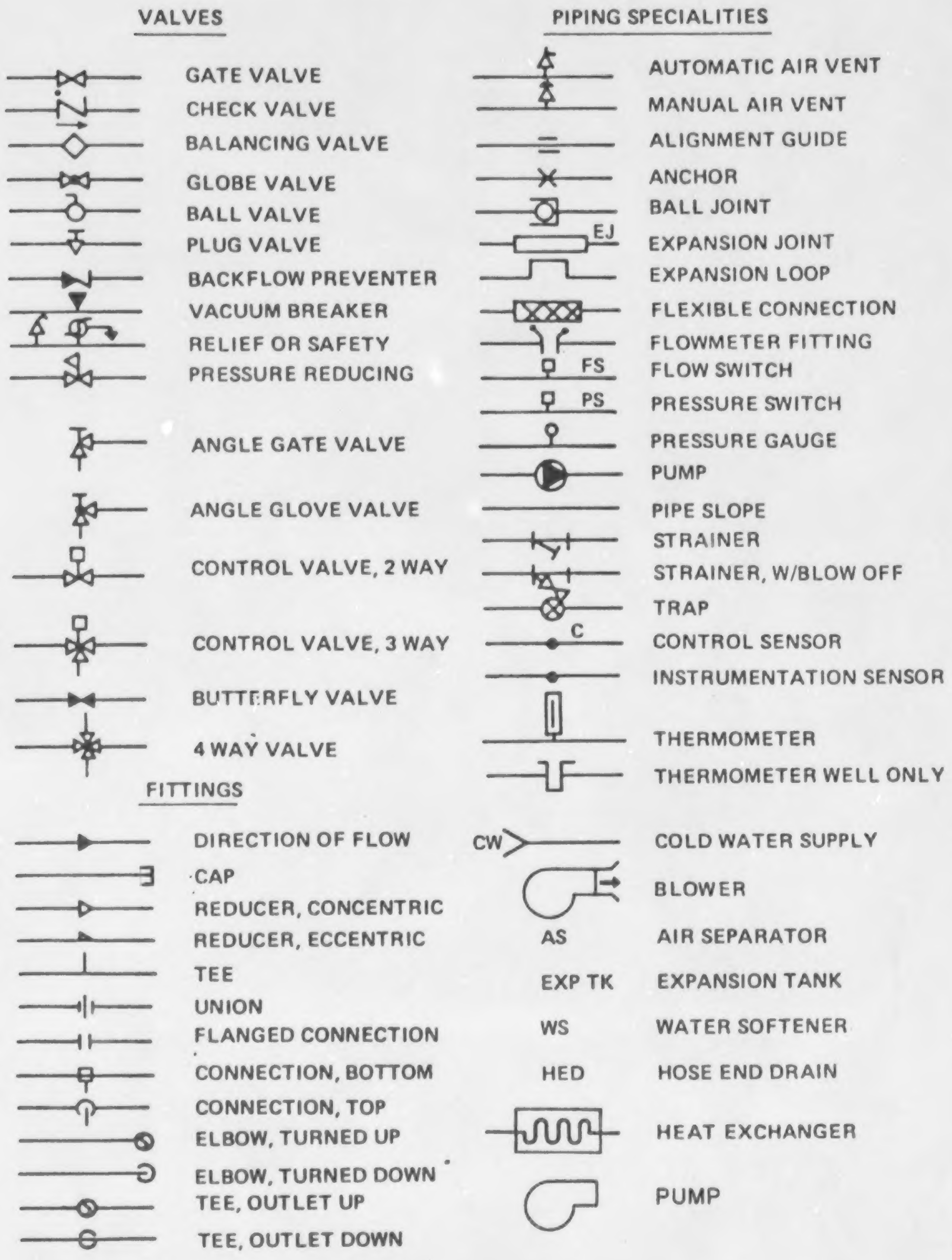
DOMESTIC ENERGY USE PATTERNS



SM-1

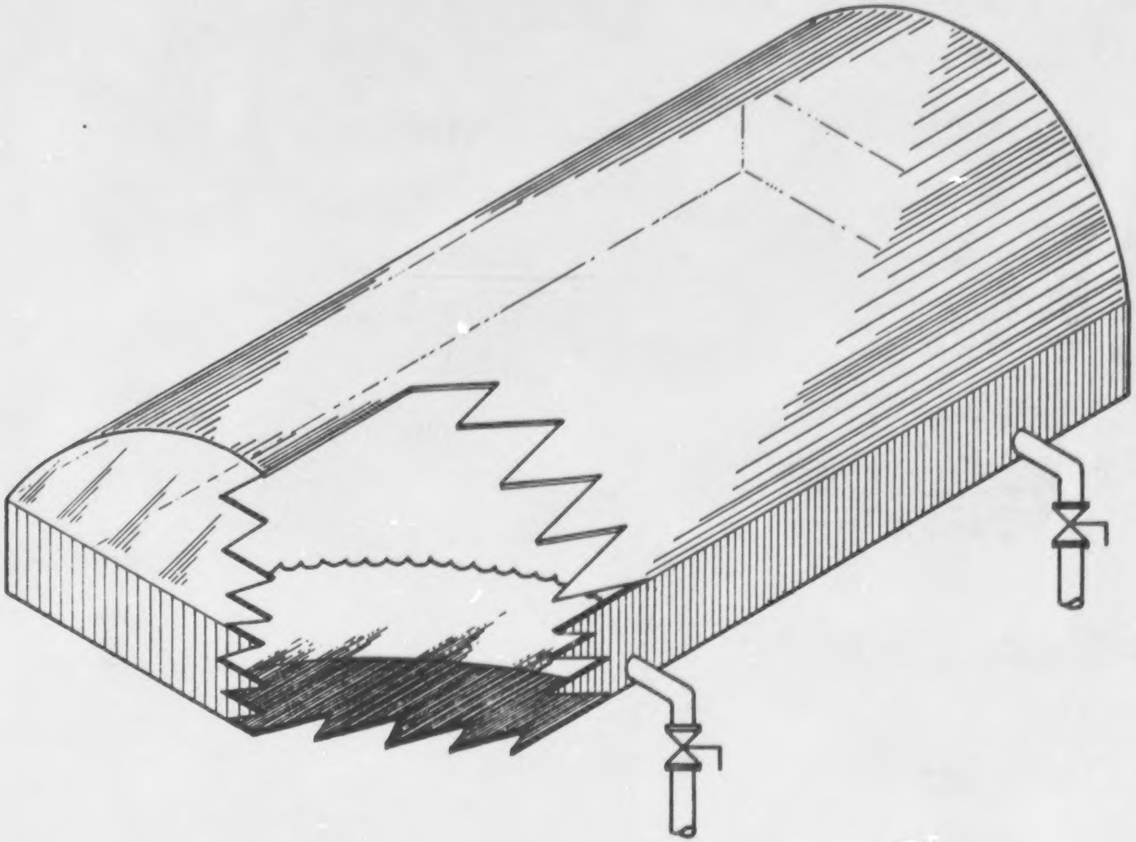
TRANSPARENCY: COLLECTORS AND ENERGY STORAGE VI-257

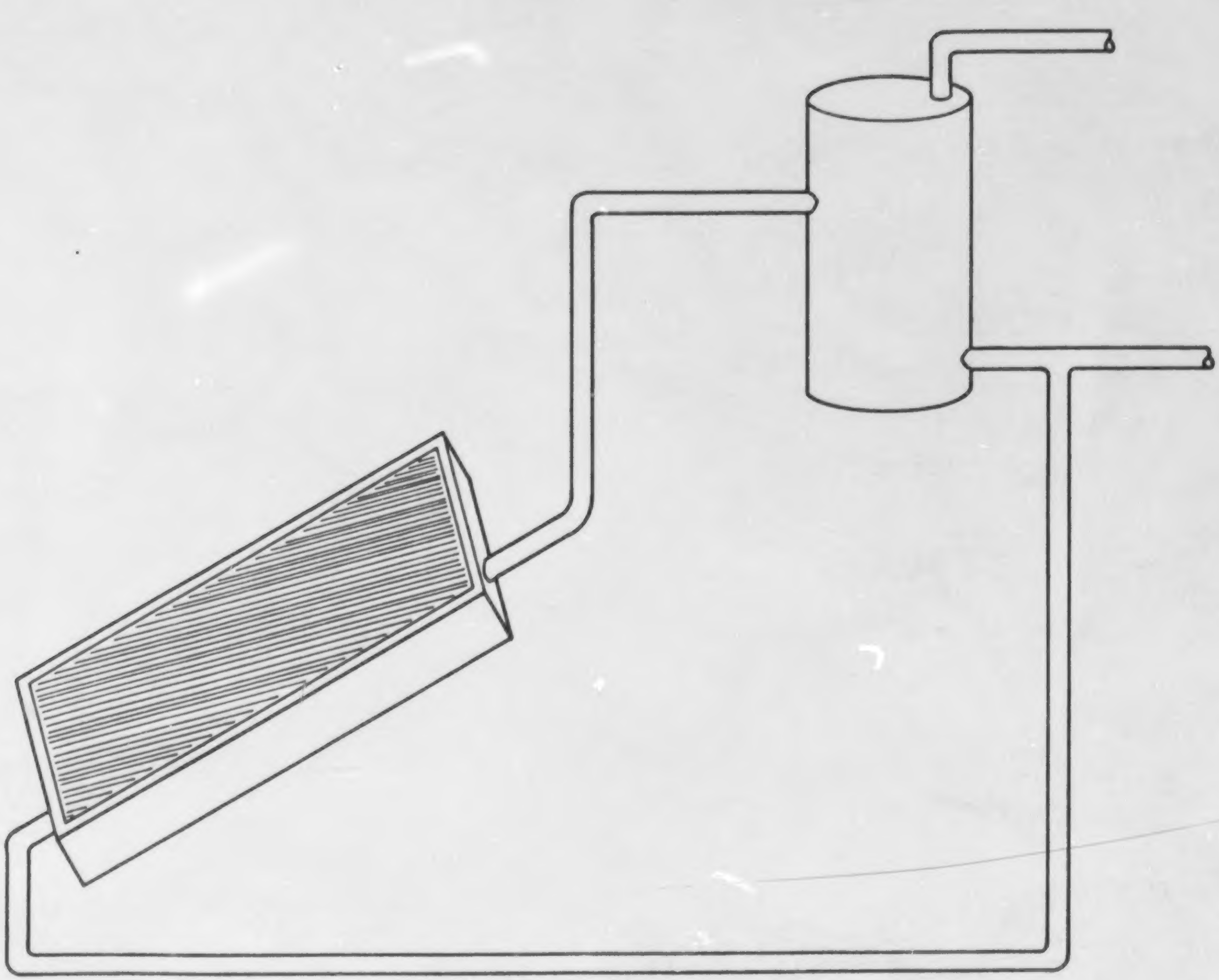
Legend For Solar System Schematics


VALVES
GATE VALVE
CHECK VALVE
BALANCING VALVE
GLOBE VALVE
BALL VALVE
PLUG VALVE
BACKFLOW PREVENTER
VACUUM BREAKER
RELIEF OR SAFETY
PRESSURE REDUCING
ANGLE GATE VALVE
ANGLE GLOVE VALVE
CONTROL VALVE, 2 WAY
CONTROL VALVE, 3 WAY
BUTTERFLY VALVE
4 WAY VALVE
FITTINGS
DIRECTION OF FLOW
CAP
REDUCER, CONCENTRIC
REDUCER, ECCENTRIC
TEE
UNION
FLANGED CONNECTION
CONNECTION, BOTTOM
CONNECTION, TOP
ELBOW, TURNED UP
ELBOW, TURNED DOWN
TEE, OUTLET UP
TEE, OUTLET DOWN
PIPING SPECIALITIES
AUTOMATIC AIR VENT
MANUAL AIR VENT
ALIGNMENT GUIDE
ANCHOR
BALL JOINT
EJ
EXPANSION JOINT
EXPANSION LOOP
FLEXIBLE CONNECTION
FLOWMETER FITTING
FS
FLOW SWITCH
PS
PRESSURE SWITCH
PRESSURE GAUGE
PUMP
PIPE SLOPE
STRAINER
STRAINER, W/BLOW OFF
TRAP
C
CONTROL SENSOR
INSTRUMENTATION SENSOR
THERMOMETER
THERMOMETER WELL ONLY
CW
COLD WATER SUPPLY
BLOWER
AS
AIR SEPARATOR
EXP TK
EXPANSION TANK
WS
WATER SOFTENER
HED
HOSE END DRAIN
HEAT EXCHANGER
PUMP

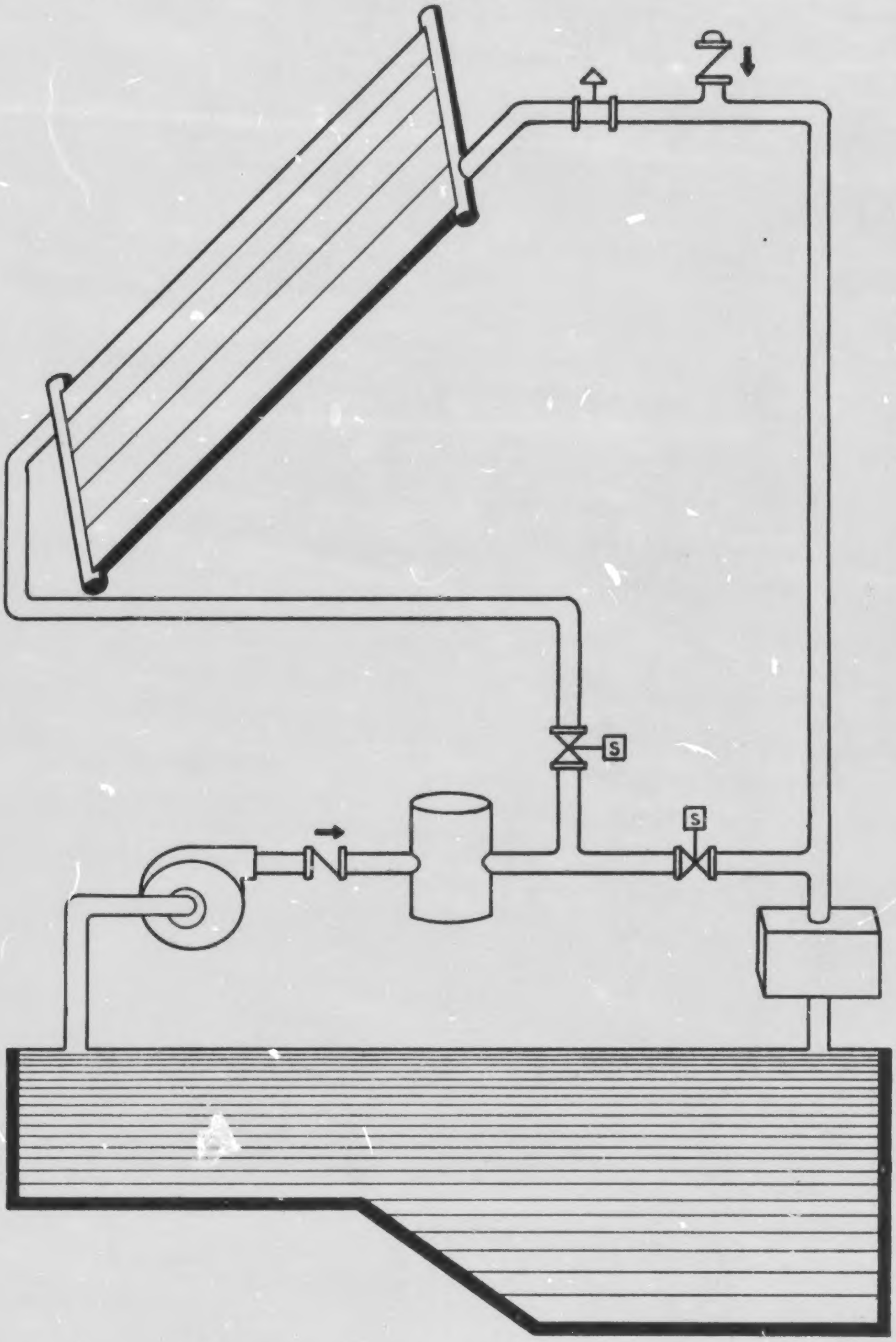
*U.S. GOVERNMENT PRINTING OFFICE: 1980 640-258-1900

BATCH-TYPE WATER HEATER



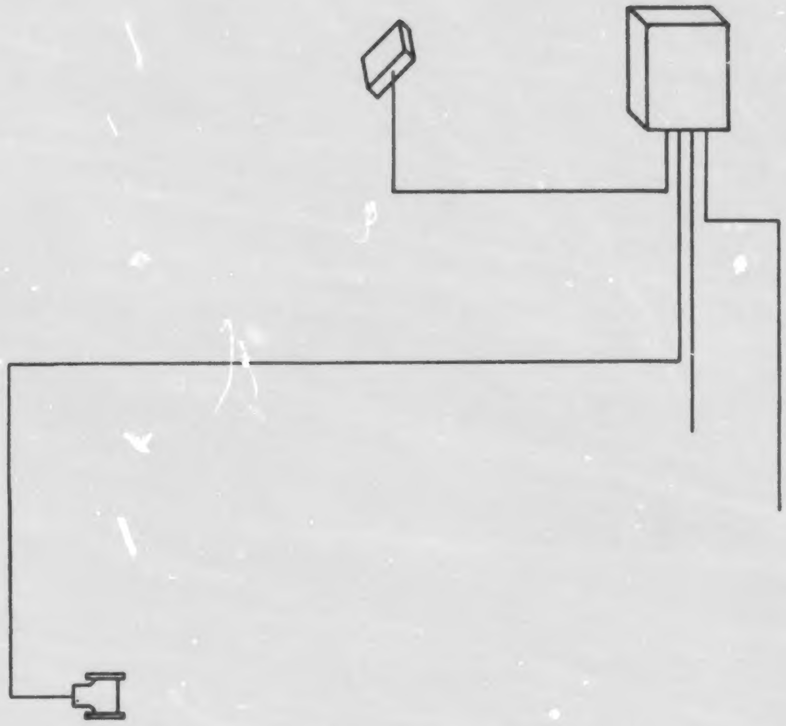


THERMOSIPHON

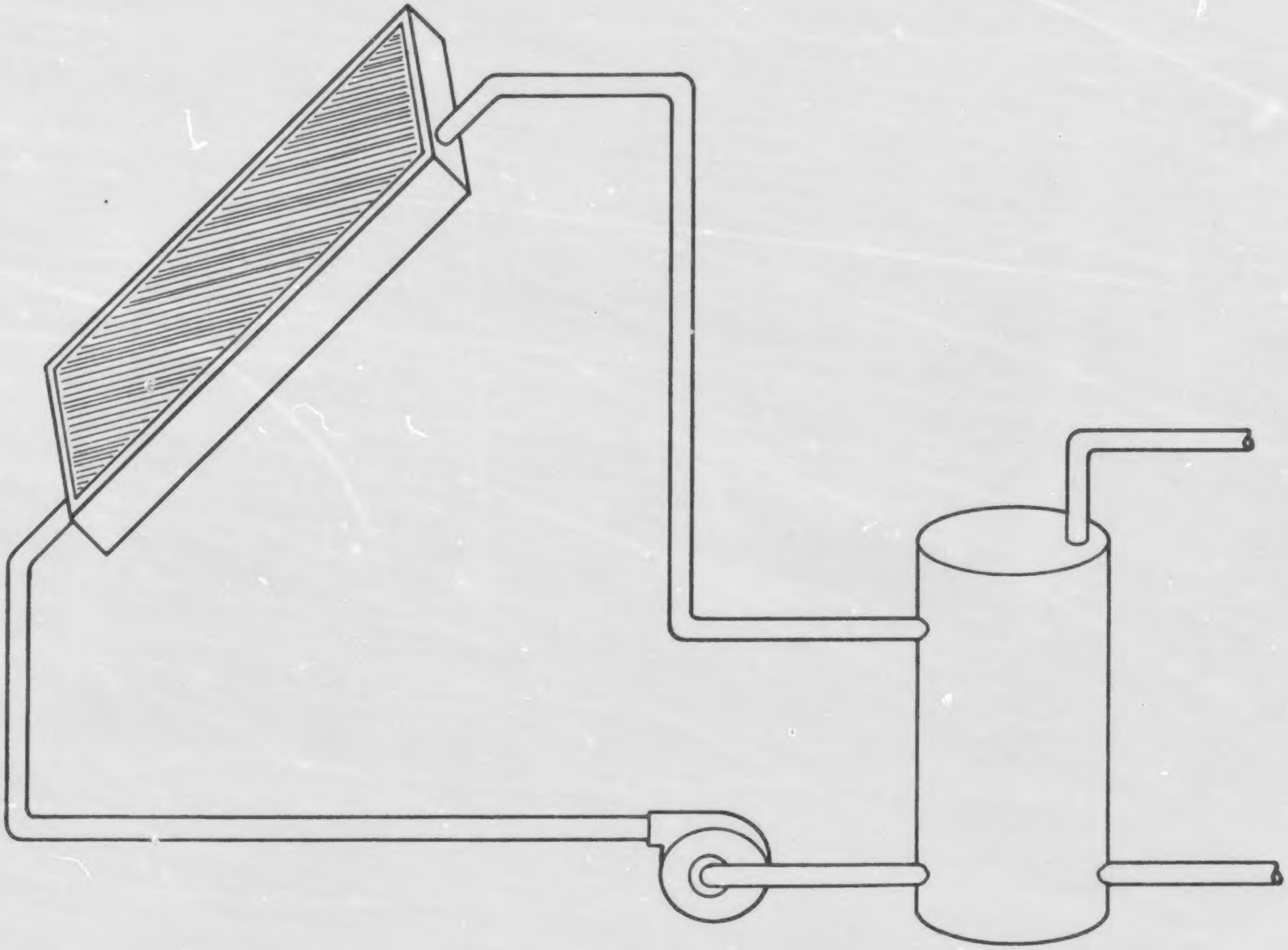


SWIMMING POOL SYSTEM

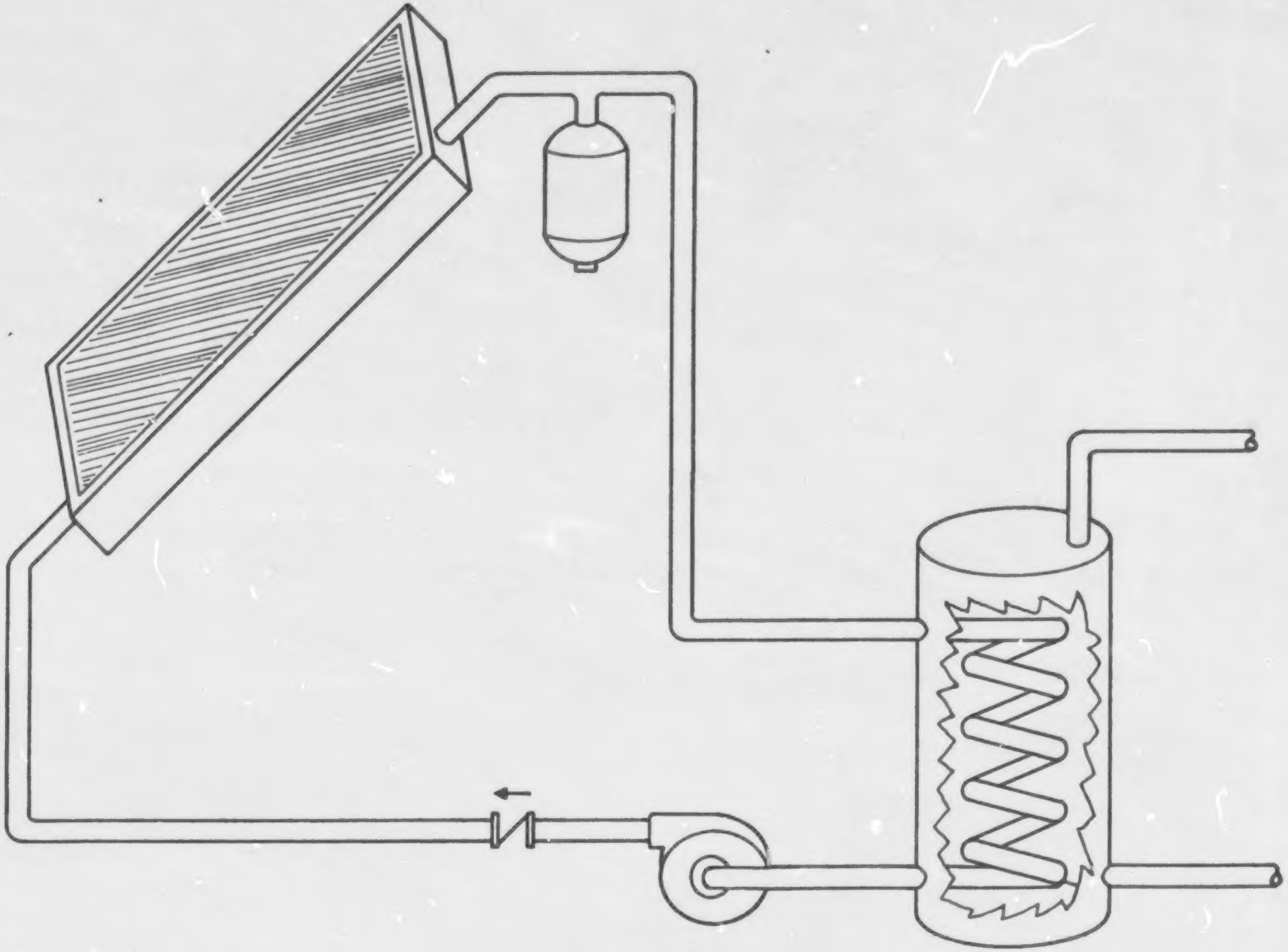
SOLAR POOL HEATER CONTROLS



CLOSED-LOOP SOLAR DHW

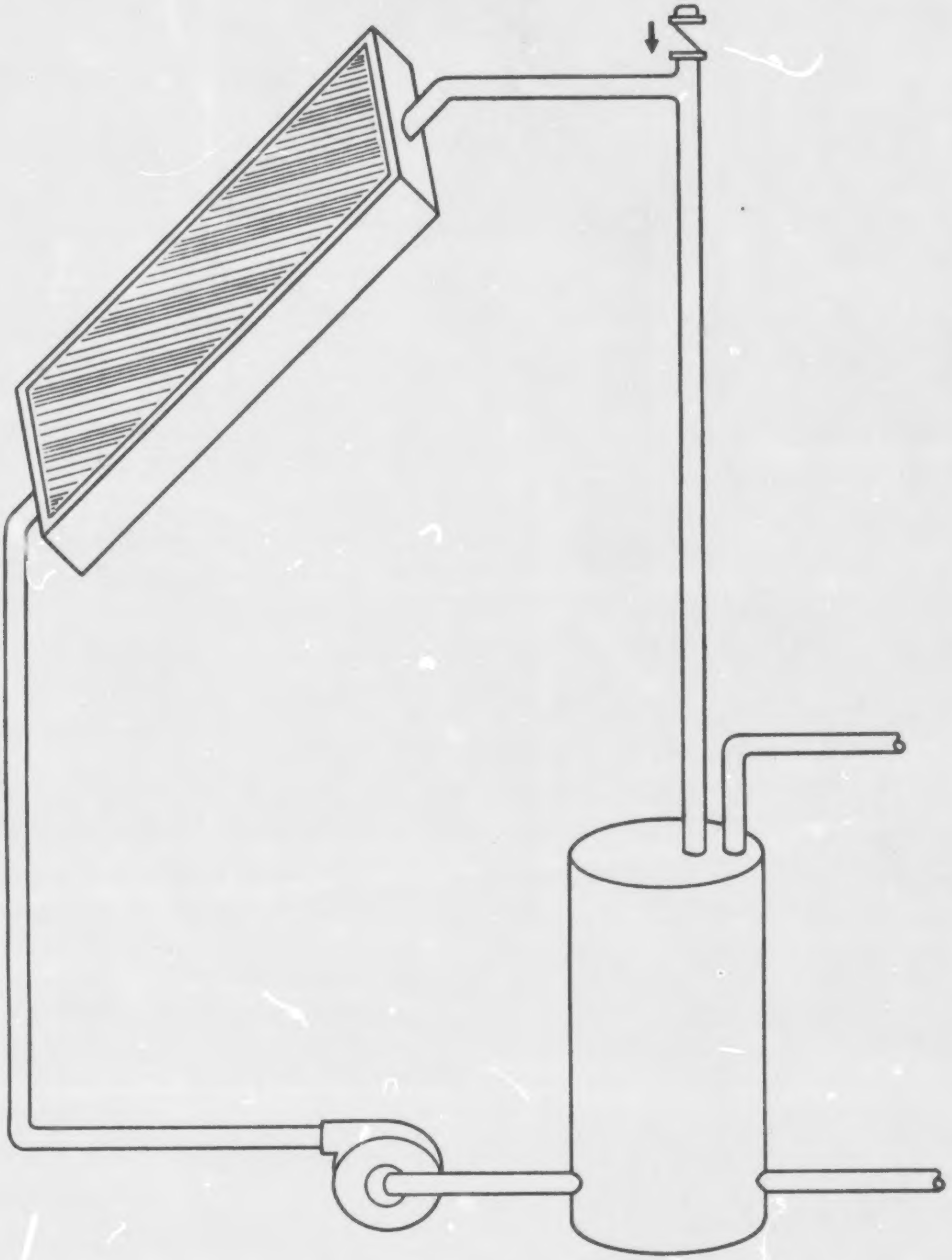


ESSENTIAL COMPONENTS OF CLOSED-LOOP SOLAR DHW

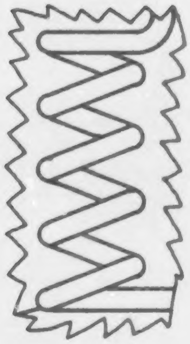


TRANSPARENCY: COLLECTORS AND ENERGY STROAGE VI-269

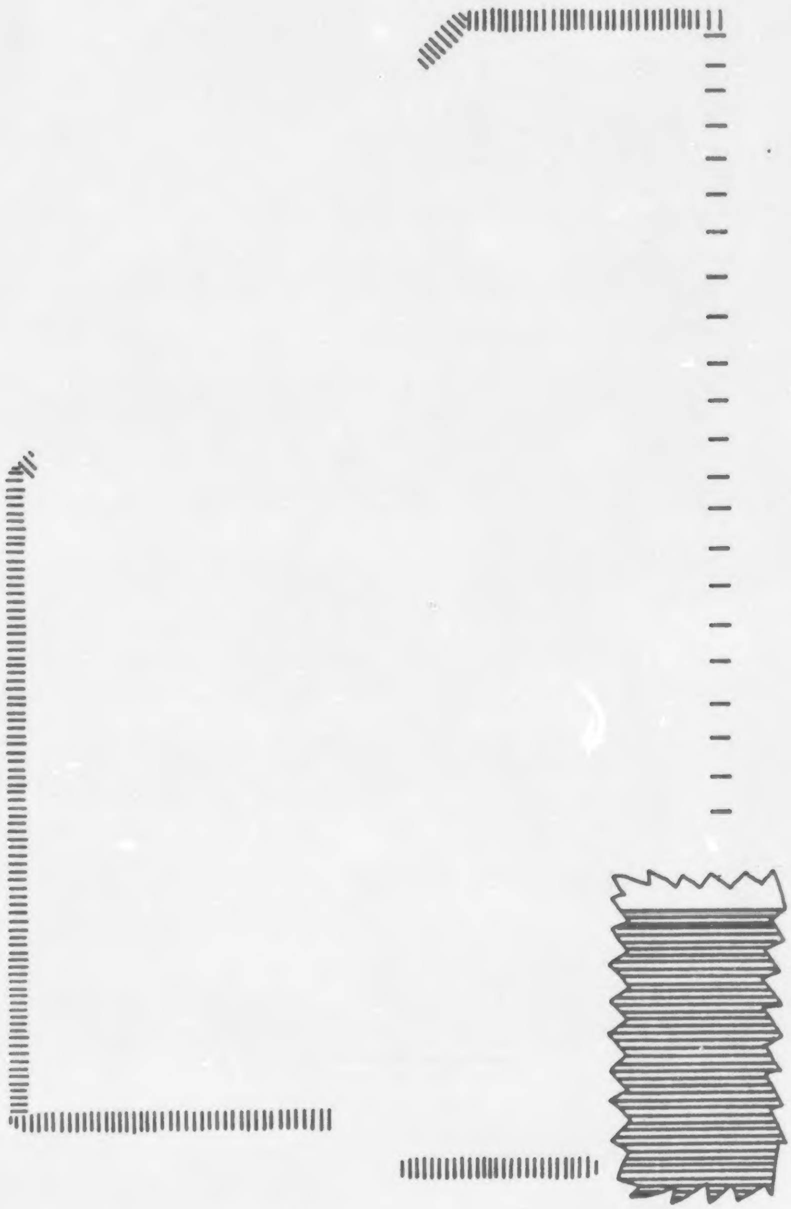
SM-6



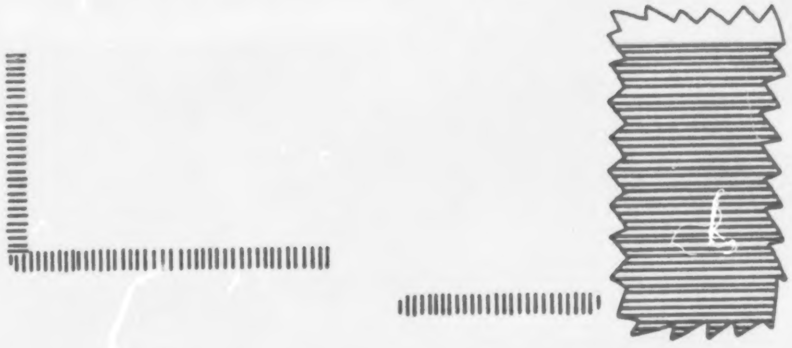
DRAIN BACK OPEN SYSTEM



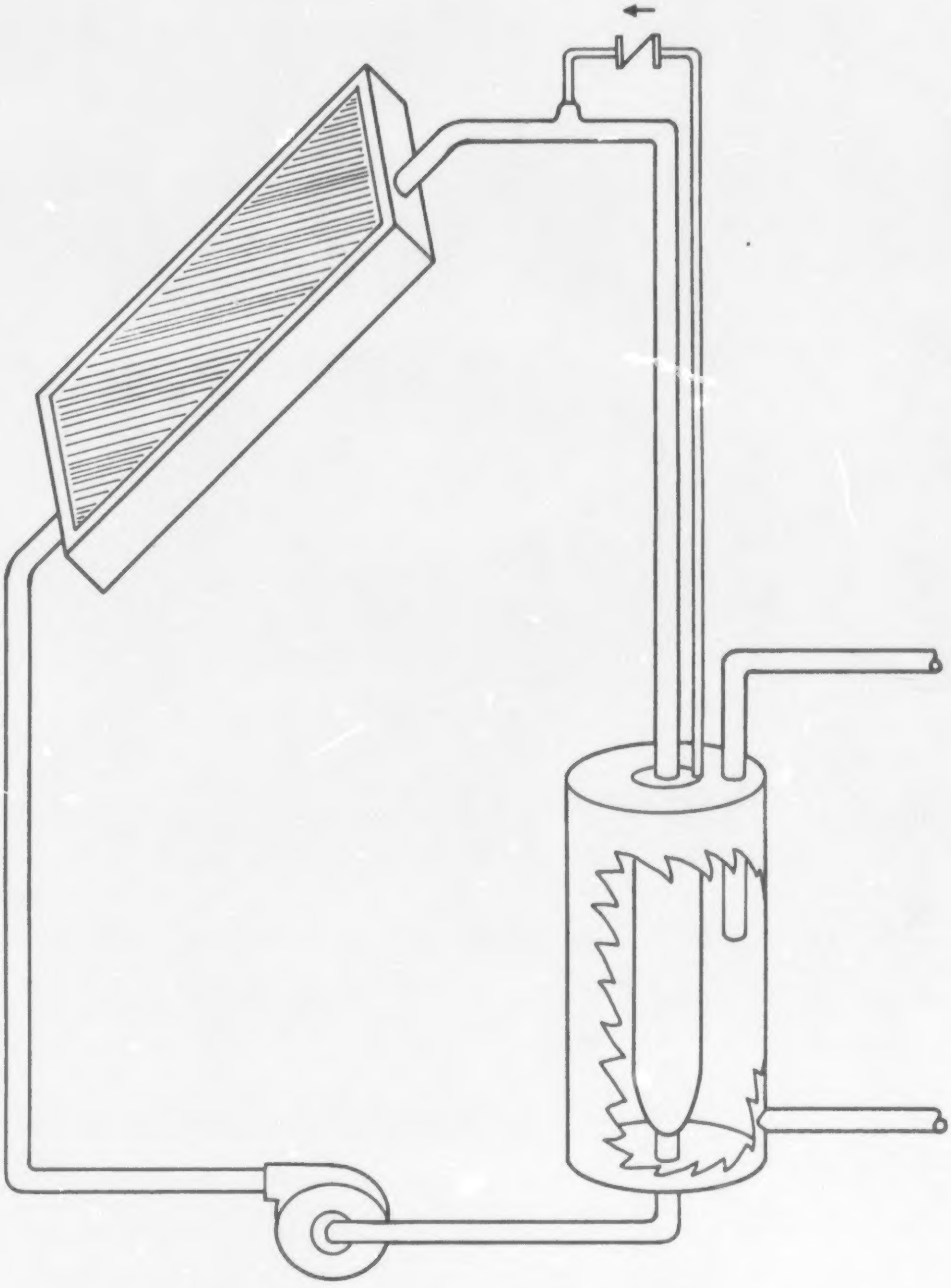
INTERNAL EXCHANGER (DRAIN BACK)



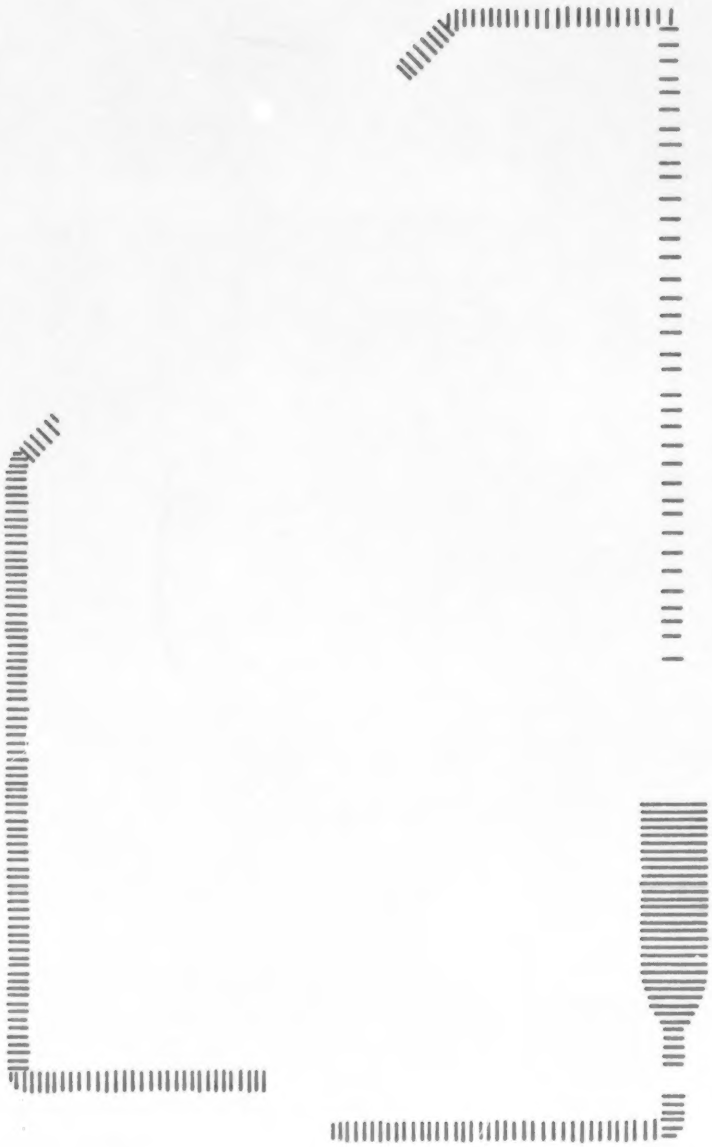
PUMP RUNNING



PUMP NOT RUNNING



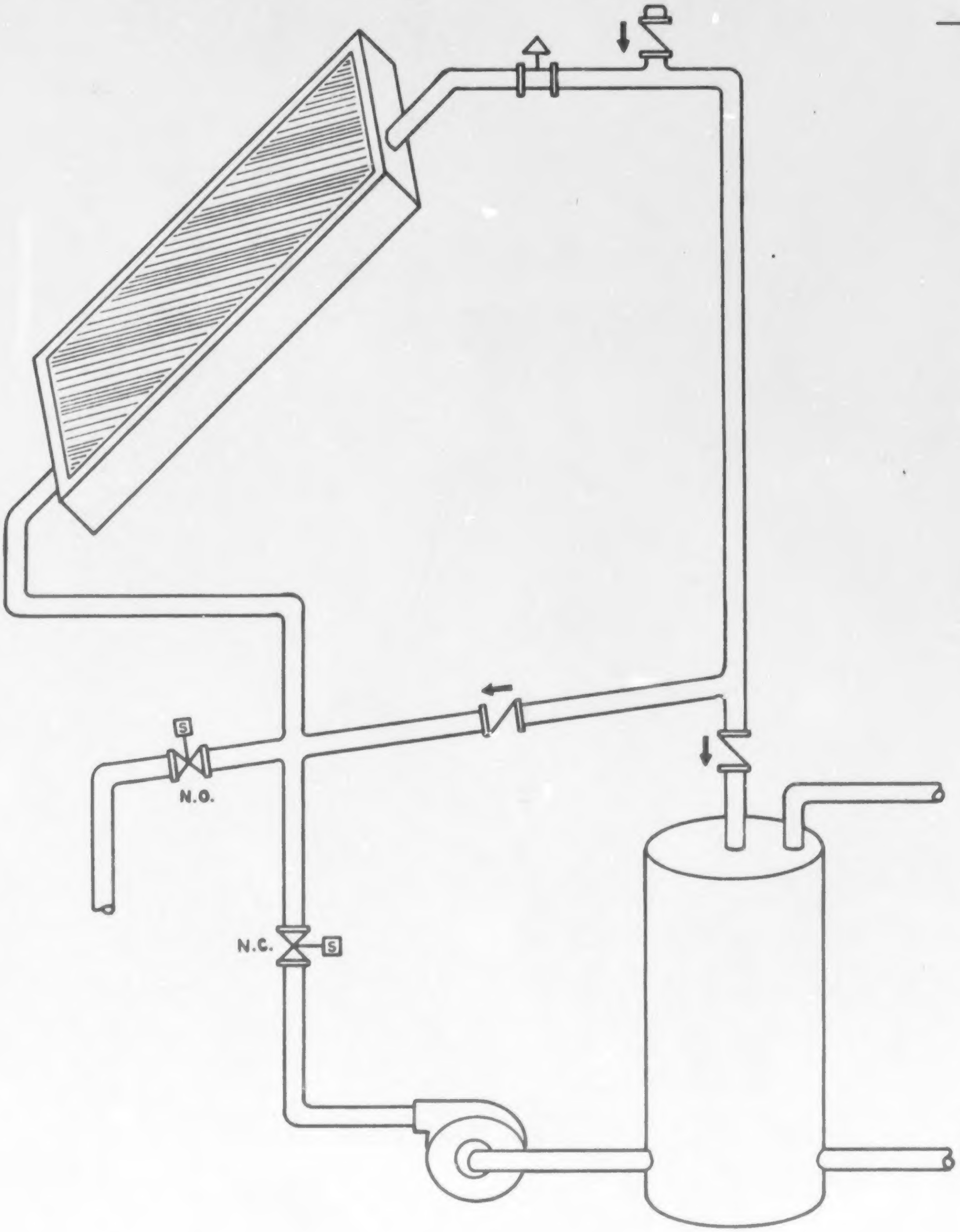
DRAIN BACK CLOSED SYSTEM



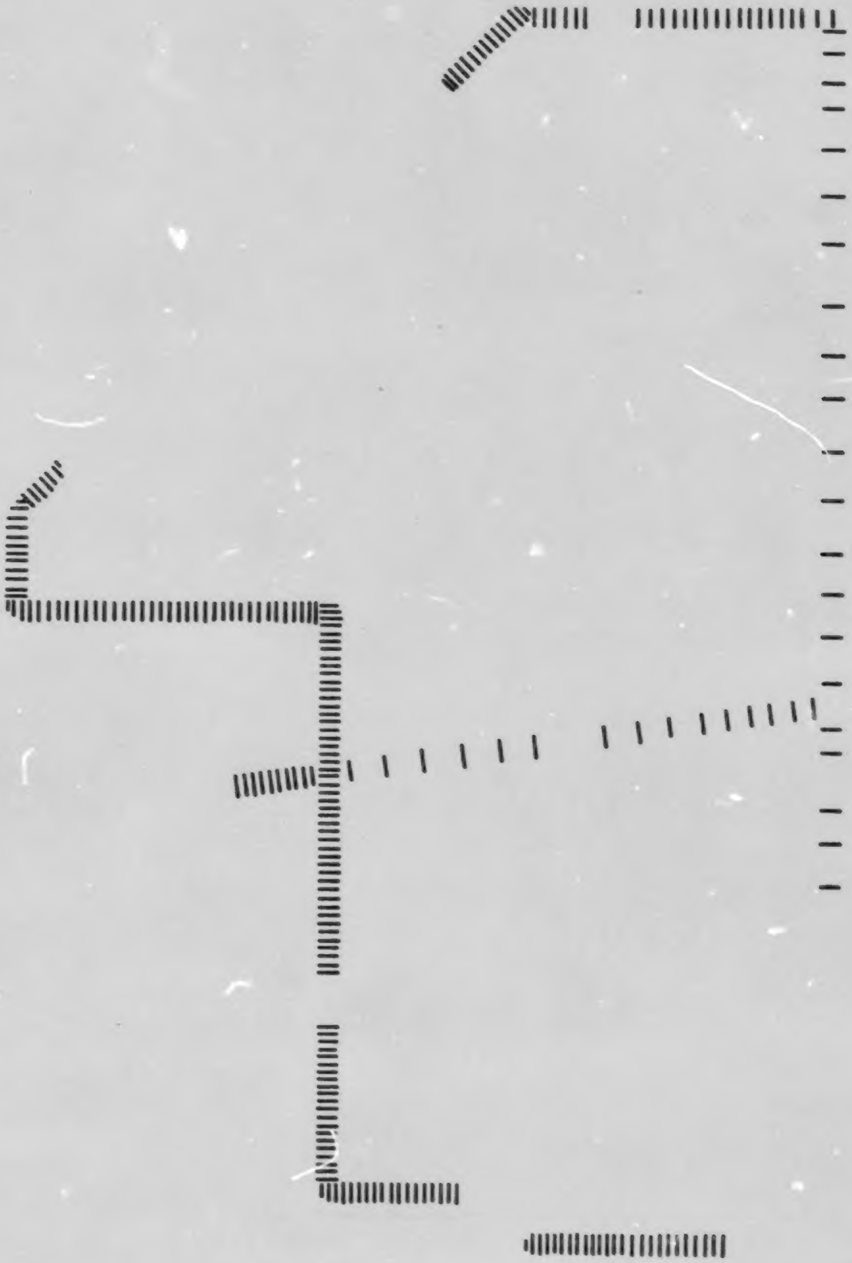
PUMP RUNNING

PUMP NOT RUNNING

957

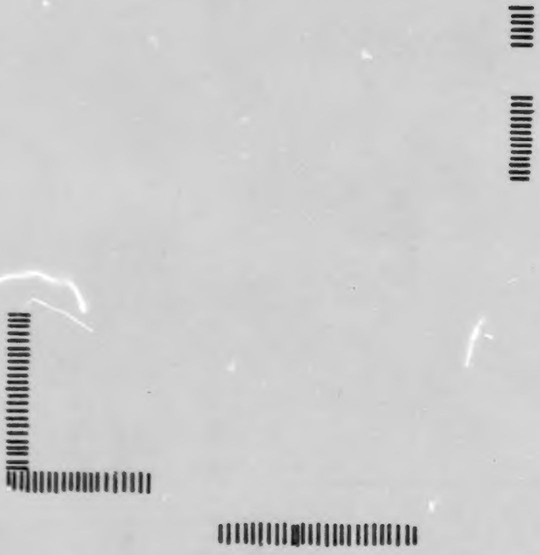


DRAIN DOWN



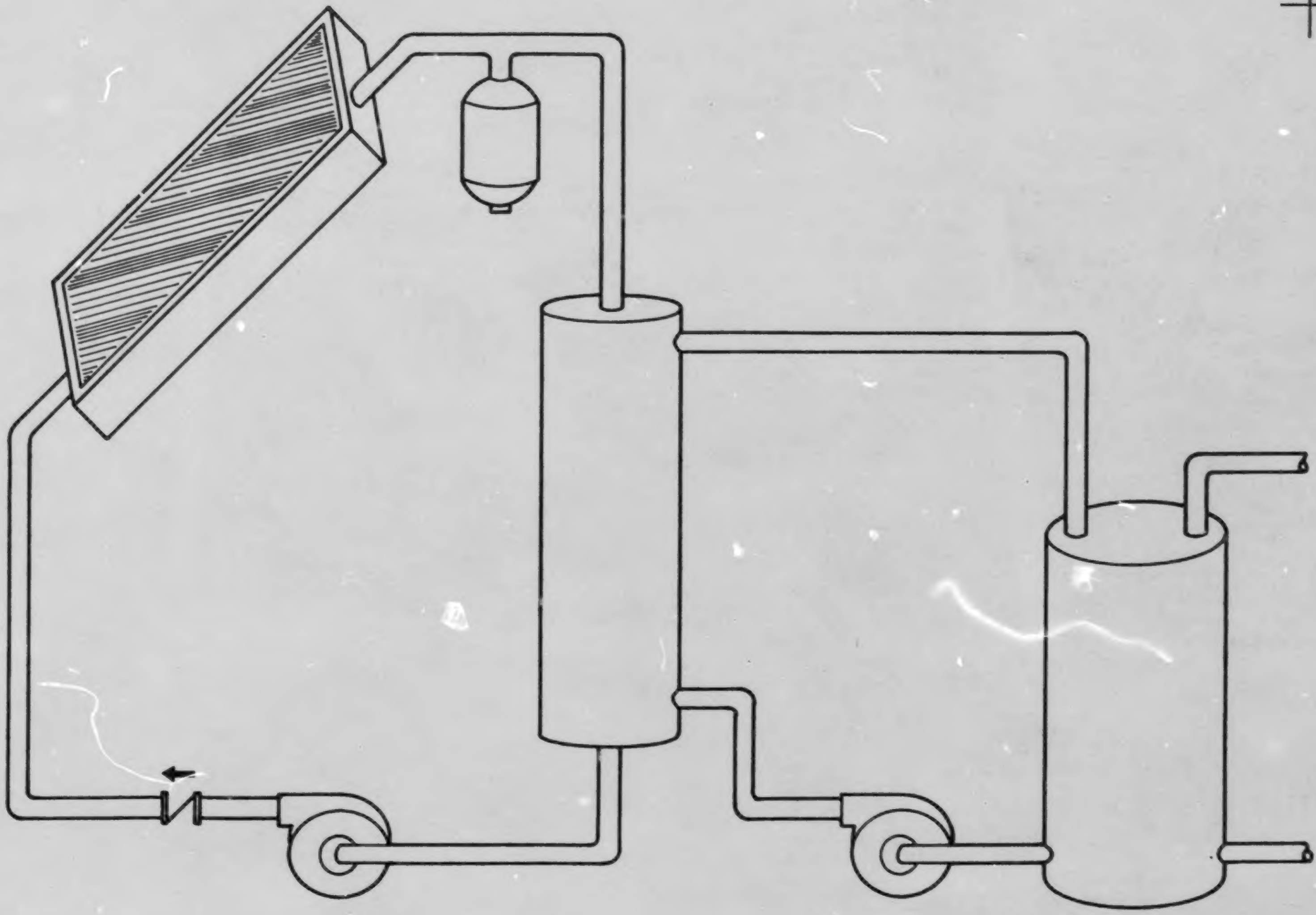
PUMP RUNNING

959



PUMP NOT RUNNING

TRANSPARENCY: COLLECTORS AND ENERGY STORAGE VI-291



SYSTEM WITH SEPARATE HEAT EXCHANGER

SM-10

COLLECTOR
ARRAY

EXPANSION
TANK

SOLAR
HEATED
WATER
OUT

HEAT
EXCHANGER

CHECK
VALVE

SOLAR PUMP

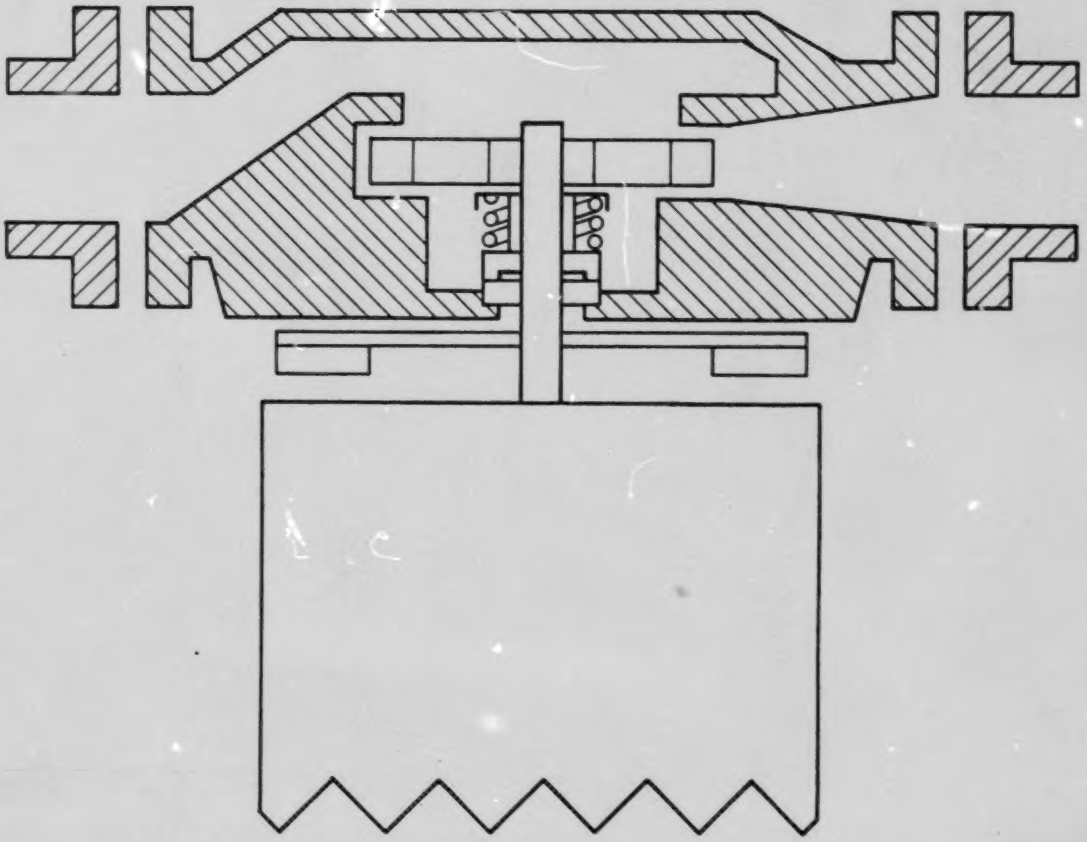
HOT WATER PUMP

CITY
WATER
IN

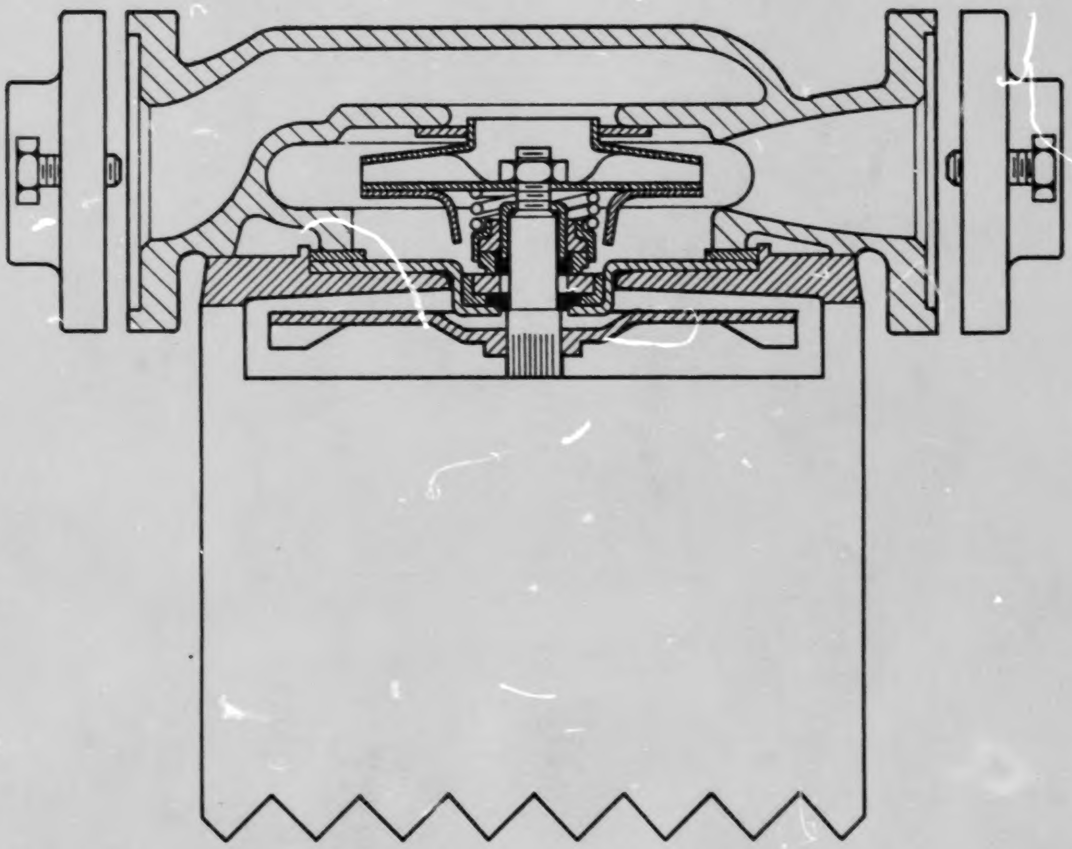
SM-10-A

COMPONENTS OF A CLOSED-LOOP SYSTEM

SOLENOID VALVE

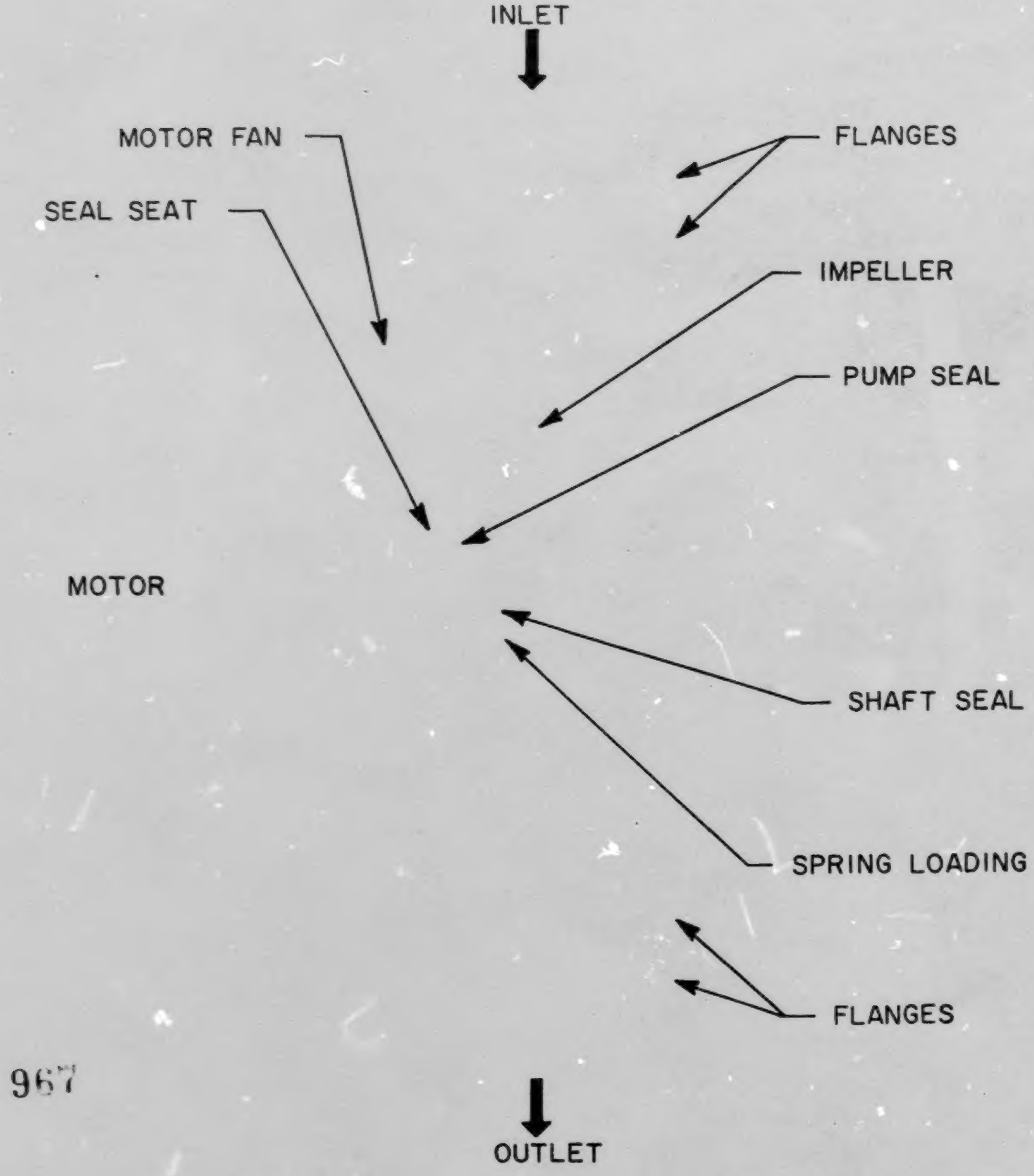


SOLENOID VALVE



TRANSPARENCY: COLLECTORS AND ENERGY STORAGE VI-299

COMPONENTS OF A SOLENOID VALVE


INLET

MOTOR FAN

SEAL SEAT

FLANGES

IMPELLER

PUMP SEAL

MOTOR

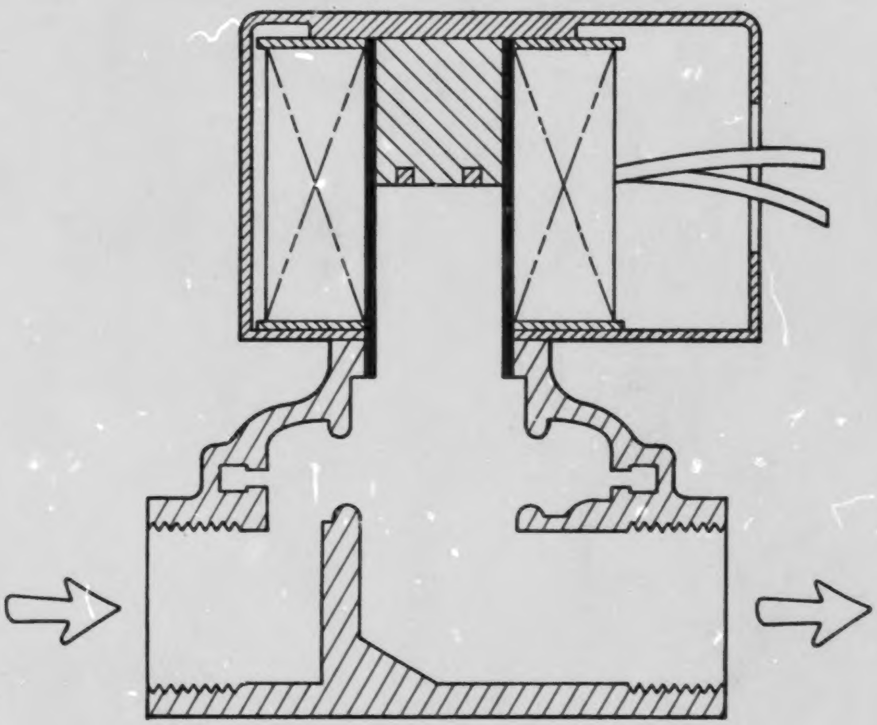
SHAFT SEAL

SPRING LOADING

FLANGES

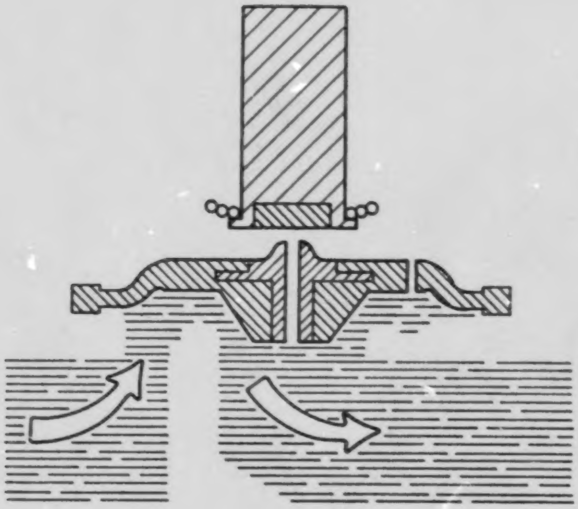
OUTLET

PC-2, 3-A

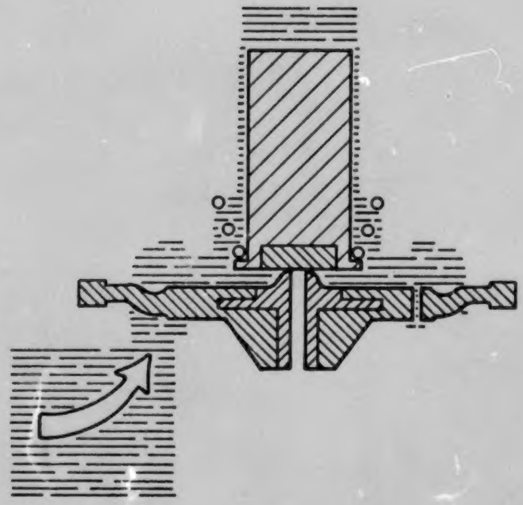


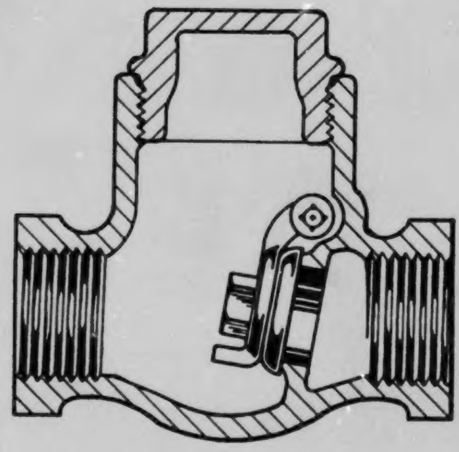
SOLENOID VALVE

FLUID FLOW THROUGH SOLENOID VALVE

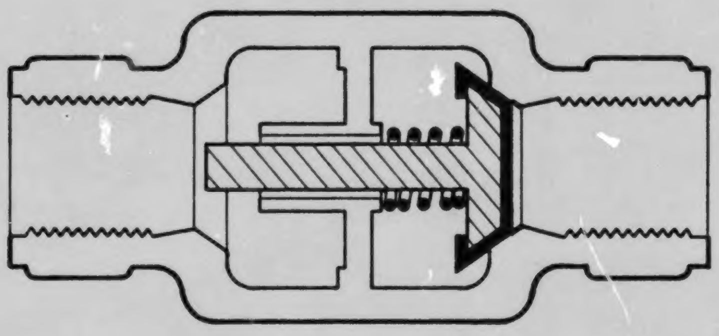


CLOSED SOLENOID VALVE

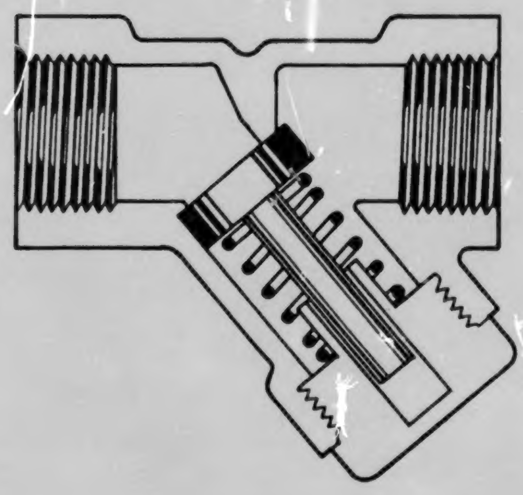




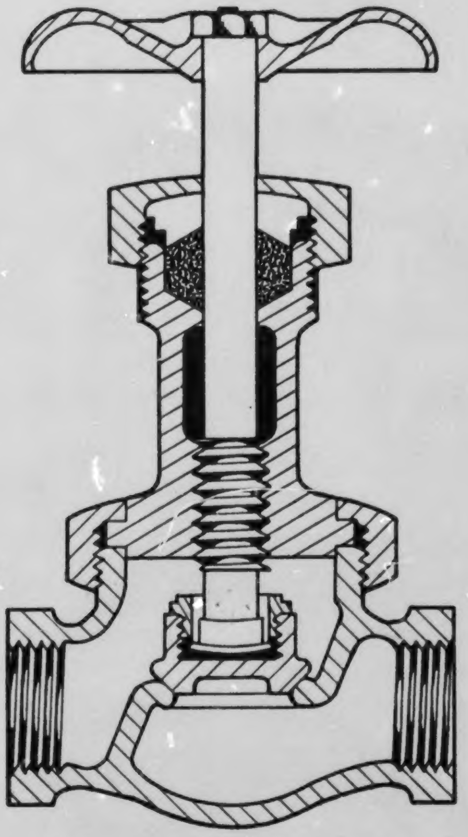
SWING CHECK VALVE



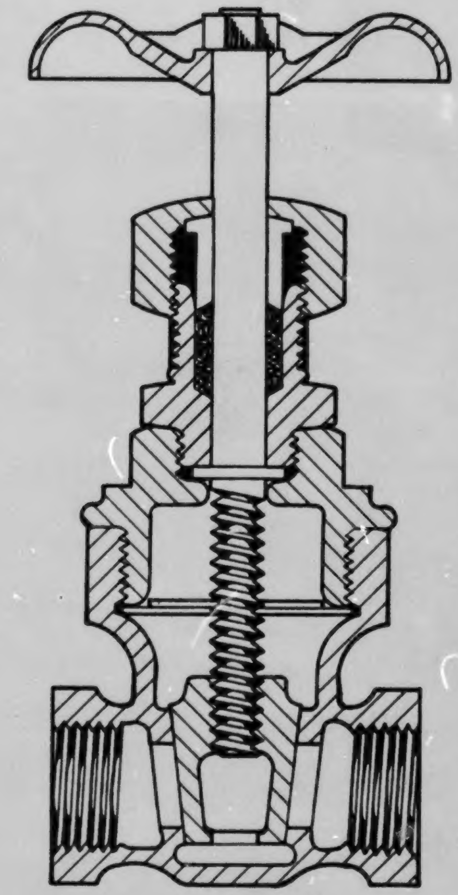
SPRING-LOADED CHECK VALVE



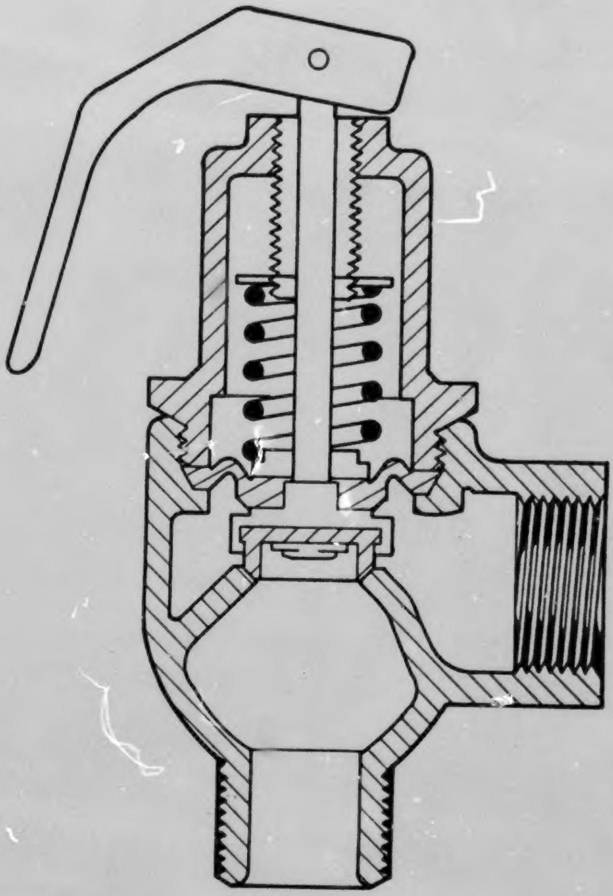
SPRING-LOADED CHECK VALVE



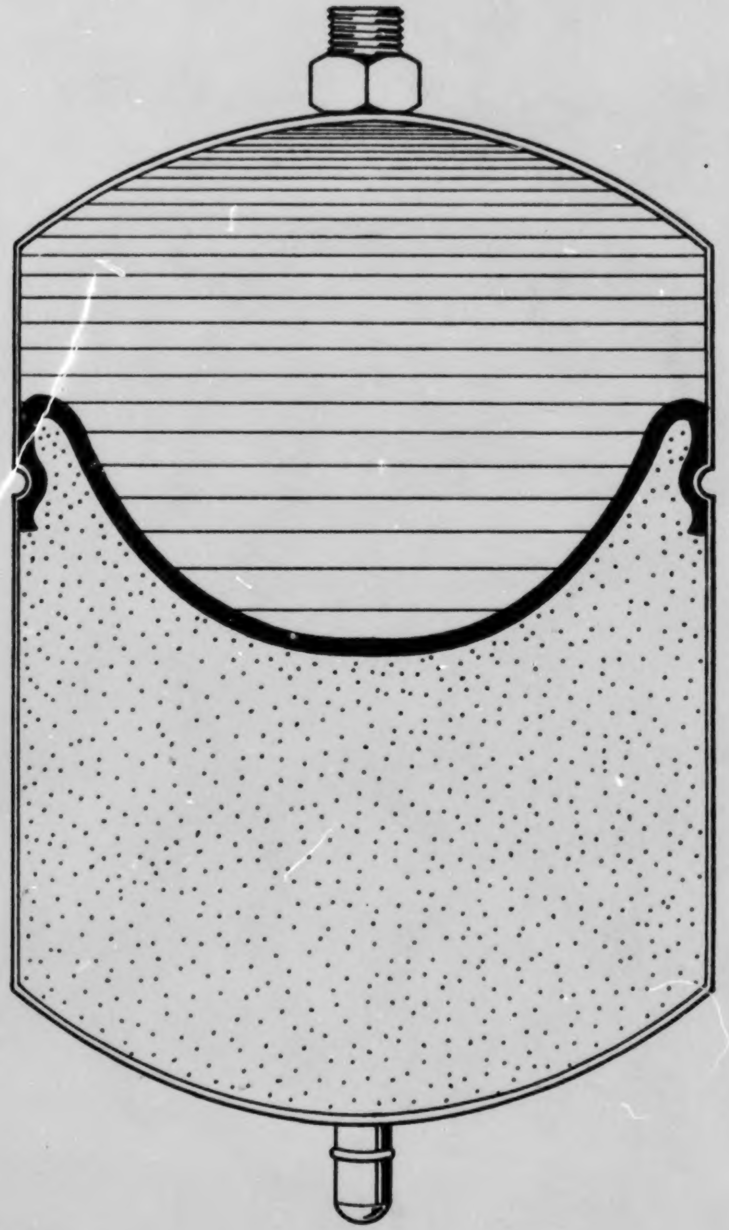
GLOBE VALVE



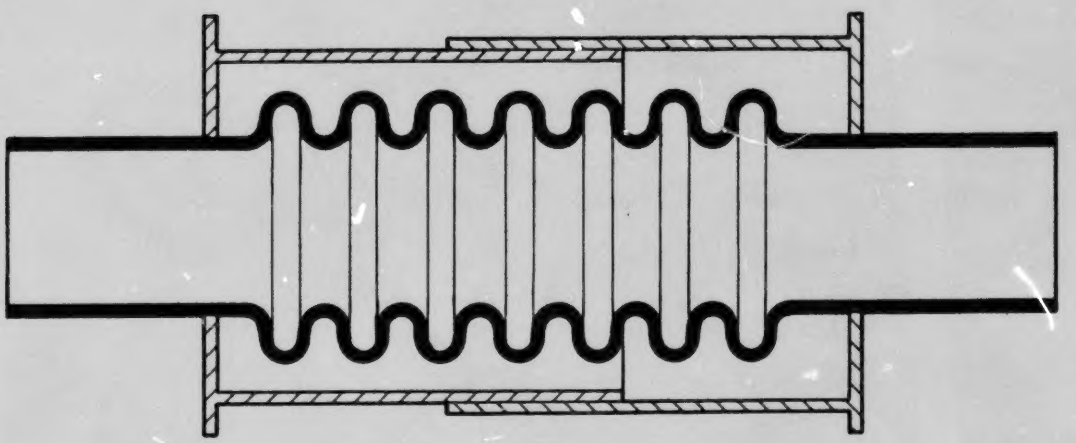
GATE VALVE



PRESSURE RELIEF VALVE

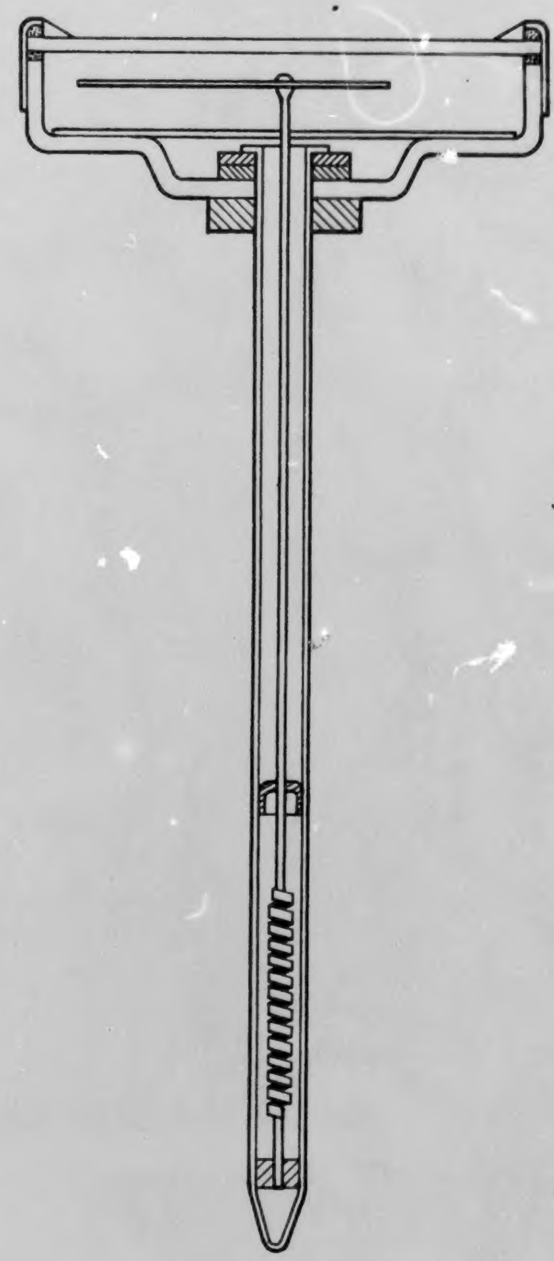


EXPANSION TANK



THERMAL EXPANSION/CONTRACTION COMPENSATOR

TRANSPARENCY: COLLECTORS AND ENERGY STORAGE VI-323



BIMETAL THERMOMETER

BT-1

GLASS

POINTER

GASKET

DIAL

GASKET

BEZEL

HEAD

HEX JAM NUT

LOCK WASHER

MOUNTING NUT

SHAFT

STEM

GUIDE SLEEVE

BIMETAL HELIX

PLUG

BIMETAL THERMOMETER
COMPONENT LABELS

ENERGY CONSERVATION AND PASSIVE DESIGN CONCEPTS

Semester Hours Credit: 3
Lecture: 3
Lab: 0

Project Director:	Charles G. Orsak, Jr.
Prime Author:	Ray Mudrak

Materials developed by
Navarro College
in cooperation with
The National Science Foundation
Project No. SED 80-19327.

INTRODUCTION:

We live in an era of higher and higher energy costs. More and more people are daily competing for the diminishing supplies of fossil fuels that remain in the crust of the earth.

It seems logical that now is the time to emphasize the importance of developing a strong concept of energy conservation in our daily living. It also represents an opportune time to direct our attention to the development of alternate and renewable energy sources. Energy Conservation and Solar Passive Design utilization in the way we build and recondition our buildings represent a great first step in diminishing the effect of fossil fuel availability and its cost. This course represents an attempt to inform and educate the student on what the options and opportunities are in dealing with this growing problem.

COURSE DESCRIPTION:

The course structure contains nine modules. The basic emphasis in the course is on conservation in personal living, in the design and construction of buildings, and in the equipment utilized in the functioning thereof. The course also places emphasis on the wise use of the sun for space heating and cooling by utilizing active, passive, or hybrid solar systems.

COURSE OBJECTIVES:

Upon completion of this course, the student should be able to:

(1) Recognize the opportunities of energy conservation associated with the design and construction of buildings.

(2) Recognize the opportunities for equipment selection for HVAC.

(3) Know how to calculate heating and cooling loads of building.

(4) Know how to utilize the sun in solar system design for heating, venti- lation, and cooling.

(5) Know how to make decisions concerning illumination requirements of various building spaces.

(6) Discuss the notable variables that define human comfort and to recommend modes of action for the solution of problems that diminish human comfort in a defined area.

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Human Comfort .... VII- 25

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Illumination Conservation .... VII- 41

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Passive Design Considerations .... VII- 63

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OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Understand energy requirements needed to transform raw materials into products that can be utilized in the construction of a building.

(2) Understand the energy requirements needed to handle a building's heating, air-conditioning, and ventilation requirements.

(3) Recognize conservation opportunities associated with residential, commercial, and transportation sectors of our energy use.

(4) Be knowledgeable on the personal decisions that one could make to effect energy conservation in our everyday living.

(5) Be able to identify intermediate and long term energy conservation decisions that will lead to better control of energy consumption.

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(2) Rouse, Robert S. and Robert O. Smith, Energy, McMillan Publishing Co., 1975.

(3) Fowler, John M., Energy and the Environment, McGraw-Hill, 1975.

(4) Ruedisili, L.C., Perspectives on Energy: Issues Ideas and Environmental Dilemas, M.W. Firegaugh, Eds., Oxford 1978.

(5) Stein, Richard G., Architecture and Energy, Anchor Press; N.Y., 1977.

(6) State of Texas Energy Auditor Training II, Texas Energy and Natural Resource Advisory Council, Austin, Texas 78701.

(7) Eccli, Eugene, Low Cost Energy Efficient Shelter For The Owner And Builder, Rodale Press, 1976.

(8) Economics of Energy Conservation, Module 11, Navarro College, TEA, Austin, Texas, 1980.

(9) Healey, Timothy J., Energy and Society, Boyd and Fraser Publishing Co., San Francisco 1976.

MODULE: CONSERVATION AS AN ENERGY SOURCE

UNIT TITLES:

(1) Energy Demand in Buildings
(2) Conservation Opportunities
(3) Conservation Decisions
(4) Economics and Social Impact

VOCABULARY:

Raw Materials
Custom Built
Space Heating
Efficiency
C.O.P.
Conservation
Insulation
Damper
Resistance Heating
Ferrous Metals
Waste Heat Recovery
Recycle
Standardized Parts
Peak Load
Tax Incentive
Kilowatt Hour
Alternating Current
Exponential Growth
Doubling Time
Technology
Passive Solar
Nuclear Energy
Fossil Fuel
Value of the Dollar
Inflation
Voltage
Amperage
Interest Rate

Constant Scale Pricing
Sliding Scale Pricing
Aesthetics
Solar Access
Deed Restriction
Simple Pay Back
Contract
Permit
Drive Train
Infiltration Losses
Thermal Conduction
Ventilation
Ton Mile
Commercial
Industrial
Berming
Subterranean Construction
Industrial Revolution
End Use
Petro Dollars
Energy Resource
Per Capita
Hydro Electric
Standard of Living
Energy Cost Profile
Social Consideration
Mechanisms of Finance
Inflation

Unit 1. Energy Demand in Buildings

- A. Energy associated in processing raw materials to become building material and getting them to the job site
  - 1. Wood framing — Reference 1, Chapter 10
  - 2. Plywood
  - 3. Fiber-glass shingles
  - 4. Cement
  - 5. Aluminum — Reference 2, Chapter 6
  - 6. Steel
- B. Energy to construct the building and to prepare the building site
  - 1. Standardized, mass-produced
  - 2. Custom-built
  - 3. Slab - berming - subterranean construction
- C. Energy to maintain a building
  - 1. Space heating and humidifying
  - 2. Space cooling and dehumidifying
  - 3. Ventilation
  - 4. Cooking — Reference 8, pp. 3-46
  - 5. Maintenance and repair
  - 6. Lighting
- D. Energy to power equipment and machinery
  - 1. Blower
  - 2. Compressors
  - 3. Transformers
  - 4. Miscellaneous

Unit 2. Conservation Opportunities

- A. Residence/commercial major targets
  - 1. Space heating and cooling
  - 2. Humidity control — Reference 1, pp. 12-44
  - 3. Water heating
  - 4. Refrigeration
  - 5. Cooking — Reference 5, pp. 189-195, pp. 280-287
  - 6. Lighting

B. Transportation sector
  1. Energy efficiency - per ton mile - cargo
    a. Ship
    b. Railroad
    c. Truck
    d. Airplane
    e. Pipeline
  2. Automobile
    a. Weight
    b. Engine and drive-train efficiency
    c. Streamlining

Reference 9, Chapter 2

Unit 3. Conservation Decisions
A. Personal conservation measures (things we can all do)
  1. Raise or lower thermostat
  2. Reduce building infiltration and thermal conduction losses
    a. Using storm windows
    b. Weather stripping
    c. Minimize door opening
    d. Close fireplace dampers when not in use
    e. Add insulation in walls, ceiling if needed
    f. Use attic ventilation and fans if needed
  3. Use high efficiency appliances and equipment
  4. Dry clothes out of doors
  5. Properly maintain heating and cooling systems
  6. Plan your driving needs - fewer miles and car-pool when you can
  7. Educate your household on energy conservation
  8. Less shower time

Reference 2, Chapter 15

Reference 3, pp. 361-381

Unit 4. Longer Term Conservation - Decisions

Reference 2, Chapter 8

- A. Live closer to where you work
- B. Improve transportation patterns

Reference 1, pp. 308-321

- C. Improve engine and drive train efficiency
- D. More standardization of major transportation components
- E. Phase out electric resistance heating
- F. Install solar domestic and space heating when and where practical
- G. Use fluorescent lights where possible

Unit 5. Industrial Energy Saving Decisions

Reference 2, Chapter 15

- A. Recycling
    1. Glass
    3. Paper
    4. Ferrous metals
    5. Motor oil
- B. Use co-generation when feasible
- C. Use waste heat recovery where feasible
- D. Build more durable products which have a longer operating life
- E. Use petro-chemicals in only most critical areas of utilization

STUDENT ACTIVITY

Exercise

Assignment:

1. Have students identify conservation techniques which can be applied at home, school, or work place and make an estimate of expected energy and money savings.
2. Have students determine the location of the nearest recycling centers for:
    a. Aluminum
    b. Glass
    c. Paper

   and find what prices are currently being paid.
3. Have students determine the efficiency of their modes of transportation and what they could do to improve them.

Unit 6. Economics and Social Impact of Energy Conservation

- A. Residential
  - 1. Heating
  - 2. Cooling
  - 3. Lighting — Reference 6, pp. 3-38
  - 4. Hot water
  - 5. Appliances
- B. Commercial and industrial
- C. Energy rates
  - 1. Constant scale pricing
  - 2. Sliding scale pricing and peak loads — Reference 9, Chapter 4
  - 3. Electric, gas metering devices
- D. Energy cost profiles
  - 1. Past (12) months
    - a. Residential
    - b. Commercial
    - c. Industrial
  - 2. Future projections
- E. Economic parameters for conservation decisions
  - 1. Incentives
    - a. Grants
    - b. Tax breaks
    - c. Decreased operating costs
    - d. Increased real estate value
  - 2. Cost of conservation
    - a. Equipment and material
    - b. Installation
    - c. Contractors cost
    - d. Service, maintenance, and operation
  - 3. Savings from conservation and economics
    - a. Less dependence on foreign suppliers

Reference 6, pp. 3-38

Reference 7, Chap. 3

  - b. Simple payback and life cycle savings
  - c. Dollars saved vs. conservation costs
  - d. Financing
  - e. Legalities
    - 1) Codes and permits
    - 2) Rights to solar access
- 4. Aesthetics and public acceptance
- 5. Contractor resistance

STUDENT ACTIVITY

Exercise

Assignment:

Utilizing utility bills provided, students should determine gas and/or electrical consumption and costs.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Recognize significance of energy conservation in relationship to building orientation.

(2) Recognize the special design and construction features known that aid in control of heat loss or gain for a building.

(3) Identify options available for consideration by the homeowner for energy conservation.

(4) Calculate heating and cooling loads of a building.

(5) Recognize magnitude of energy associated with domestic hot water needs.

(6) Discuss the operation of an electric or gas water heater.

(7) Discuss water saving options associated with the home.

(8) Compute the cost associated with the operation of various household appliances.

(9) Determine the feasibility of applying solar heated water actively or passively toward needs of the home.

(10) Recognize and detail a number of maintenance procedures that could be applied to energy conservation in the home.

(11) Discuss and identify energy conservation options associated with ancillary equipment choices.

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UNIT TITLES:

(1) Building Structural Elements

(2) Heat Loss and Heat Gain

(3) Ancillary Equipment

(4) Building Variables

(5) Energy Conservation Opportunities

VOCABULARY:

Building Orientation
Heat Loss
Heat Gain
Degree Day
Indoor Design Temperature
Outdoor Design Temperature
Humidity Load
Infiltration
Insolation
Insulation
Sun Rights
Thermal Domestic Hot Water Load
Zoning
Wall Ratio to Floor Area
Thermostat
Thermal Conductivity
Heat Transfer Coefficient
Inside Air Film
Outside Air Film
Load Formula
Annual Heating Load Index
Annual Cooling Load Index
Equipment Gain
Duct Loss
Conduction Loss
Window Solar Gain
Property Covenant
Btu
Kilowatt Hour
R-Valve

Unit 1. Structural Elements
- A. Preliminary building considerations
  - 1. Insulation before insolation

Reference 1,
Modules 5, 8, and 9

  - 2. Weatherstripping and caulking
  - 3. Thermal efficiency and glazing
  - 4. Awnings, shade, and overhang
- B. Building site and orientation
  - 1. North - south exposure

Reference 2,
Module 3

  - 2. East - west exposure
  - 3. Actual and potential aspects of shading
  - 4. Sun rights
- C. Structural materials

Reference 11,
Module 6

  - 1. Type and mass
  - 2. Load bearing capacity
  - 3. Thermal properties and characteristics
  - 4. Cost and durability

Reference 3,
pp. 555-586

- D. Codes, property covenants, zoning
- E. Occupant utilization
  - 1. Space usage

Reference 1,
Module 21

    - a. High/use
    - b. Low/use
  - 2. Energy demand patterns

Unit 2. Heat Loss and Heat Gain
- A. Load factors

Reference 4, Chapter 1-8
Reference 5, Section 3-9
Reference 6, pp. 1-24

  - 1. Heat transfer - review
    - a. Conduction
    - b. Convection
    - c. Radiation
  - 2. Thermal conductivity

Reference 11,
Module 13

    - a. Thermal conductance
    - b. Thermal resistance
      - 1) 1/K
      - 2) 1/C
      - 3) 1/K thickness
- B. Heat transfer coefficients (U factor)
  - 1. Resistance of homogeneous materials
  - 2. Resistance of total of two or more materials

Reference 11,
Module 13

  - 3. Air films (in and out)
  - 4. U factor calculation
- C. Load formula $Q = U A \Delta T$
  - 1. Define the variables

Reference 6,

Reference 6, Chap. 5-8

Reference 11,
Module 13

Reference 6, Chapter 5-8
Reference 8, Chapter 5 & 10
Reference 6, Chapter 9-12
Reference 12, Chapter 7
Reference 12, Chapter 7

Reference 11,
Module 13
Reference 12, Chapter 7

Reference 13, Chapter 5

in the above equation

2. Define
    a. Indoor design temperature
    b. Outdoor design temperature
    c. Degree day
    d. Btu per degree day

D. Heat load calculation
    1. Conduction losses
       $Q = U A \Delta T$
    2. Infiltration losses

       $Q = 0.018\ V\ ft^3/hr\ \Delta T$

    3. Humidity losses
    4. Duct losses
    5. Window gains
    6. Equipment gain
    7. People gain

E. Building Heat Load
    1. Btu/hr.
    2. Btu/degree day
    3. Btu/mo. (coldest mo.)
    4. Btu/yr.

F. Annual building heating load index Btu/ft^2 yr.

STUDENT ACTIVITY

Assignment:

1. Visit local architect's office and borrow a set of house plans. From information on those plans calculate the heating load by calculating:

    a. Thermal conduction load in Btu/ft^2/hr

       for January:
       1. Walls
       2. Windows
       3. Ceiling
       4. Floors

    b. Infiltration load in Btu/ft^2/hr.

    c. Duct losses if any Btu/ft^2/hr.

    d. Humidity load Btu/ft^2/hr.

    e. Window solar gain

    f. Equipment gain
       1. Kitchen
       2. Water heater

g. Design temperature difference

h. Btu/degree day

i. January heat load

j. Annual heat load

k. Annual heating energy index

$Btu/ft^2/yr.$

2. Calculation of building cooling load
   a. Cooling load calculation
      1. Conduction load
      2. Infiltration load
      3. Humidity load
      4. Duct load (if any)
      5. Window load
      6. Equipment load
      7. People load
   b. Building cooling load
      1. $\frac{Btu}{Hr}$
      2. $\frac{Btu}{\text{degree day}}$
      3. $\frac{Btu}{Mo}$ (hottest month)
      4. $\frac{Btu}{Yr.}$
   c. Annual building cooling load index

$$\frac{Btu}{ft^2/yr.}$$

Reference 11,
Module 13
Reference. 12,
Chap. 7

STUDENT ACTIVITY

Assignment:

From the same set of plans from the previous STUDENT ACTIVITY, calculate the following cooling load by doing the following:

A. Calculate the August conduction load for (in Btu/ft^2 hr):
   1. Walls
   2. Ceiling
   3. Windows
   4. Floors

B. Calculate the August infiltration load

C. Calculate the equipment load
   1. Kitchen
   2. Water heater

D. Load associated with solar window gain

E. Humidity load
F. Duct losses if any
G. Design temperature difference
H. Btu/degree day
I. August cooling load
J. Annual cooling load
K. Annual cooling load index
Btu/ft^2/yr.

Unit 3. Ancillary Equipment

Reference 10, pp. 1-17

Reference 6, Chapter 15

Reference 8, Chapter 12 & 13

A. Domestic hot water and usage patterns
  1. People
  2. Appliances
  3. Scheduled usage
  4. Temperature requirements
    a. Kitchen
    b. Laundry
    c. Personal hygiene
  5. Equipment options
    a. Electric
    b. Gas
    c. Solar
  6. Thermal load

Reference 8, pp. 17-21

B. Refrigerators and freezers
  1. Defrost
  2. Door type
  3. Thermal insulation
  4. Frequency of opening
  5. Thermostat setting

STUDENT ACTIVITY

Assignment:

Given: A family of four people

Tap water temperature of 55° F

Use water temperature of 125° F

Calculate:

A. The thermal load for the above family per month for domestic hot water. (Btu)

B. If electric energy is available at seven cents per KWH and the overall efficiency of the electric hot water system is 80 percent, calculate the hot water costs per month.

C. Dishwasher
   1. Temperature of water

Reference 9, pp. 13-14

   2. Scheduling
   3. Dry cycle
   4. Volume for wash

D. Washing machine

Reference 8, Chapter 13

   1. Gas vs. electric
   2. Scheduling

Reference 9, pp. 14-15

   3. Volume per rinse and number of rinses
   4. Temperature water

E. Clothes dryer
   1. Gas vs. electric

Reference 8, Chapter 13
Reference 6, Chapter 14

   2. Scheduling
   3. Venting
   4. Temperature
   5. Use clothes line

F. Kitchen appliances
   1. Gas vs. electric

Reference 9, pp. 17-20

   2. Scheduling
   3. Microwave
   4. Pan sizing

STUDENT ACTIVITY

Assignment:

A family uses an electric dryer for 10 hrs. per week. When the dryer is operating it uses electrical power at a rate of five thousand watts. Calculate the monthly cost to operate the dryer for a 30 day month at an electric rate of seven cents per KWH.

Unit 4. Building Variables

A. Size and shape for conservation of energy effects
   1. Area exposed

Reference 12, Chapter 13

   2. Perimeter considerations
   3. Ratio of wall area to floor area
   4. Over hang

B. Insulation values

Reference 12, Chapter 7

   1. R value for walls, windows, and doors
   2. R value for ceilings
   3. R value for floors and perimeter of slab
   4. Air films and wind breaks
   5. Inside or outside the thermal mass

- C. Infiltration aspects
  - 1. Wind speed and direction
  - 2. No. of doors and windows — Reference 13, Chapter 4
  - 3. Tightness of doors and windows
  - 4. Single or multiple units
  - 5. Humidity considerations
  - 6. Design temperature difference considerations
  - 7. Frequency of door use
- D. Attic conditions
  - 1. Insulated or not
  - 2. Vented - natural - peak or soffit
  - 3. Vented - power
  - 4. Deep or narrow pitch
  - 5. Temperature swing or variation
- E. Blinds - awnings
  - 1. Inside
  - 2. Outside — Reference 12, Chapter 3
  - 3. South - north wall
  - 4. East - west wall — Reference 13, Chapter 4
  - 5. Awnings
- F. Curtains
  - 1. R value
  - 2. Color
  - 3. Open or closed
- G. Site aspects
  - 1. Surface
  - 2. Bermed — Reference 13, Chapter 4
  - 3. Subterranean
- H. Color Details
  - 1. Roof
  - 2. Walls
  - 3. Inside surface

Unit 5. Energy Conservation Opportunities

- A. More insulation
  - 1. Roof - attic - venting
  - 2. Walls
  - 3. Add storm windows and doors
- B. Less infiltration
  - 1. Tight-fitting doors
  - 2. Caulk windows - use weatherstripping — Reference 13, Chapter 4
  - 3. Use double door - foyer

    4. Tape up leaks in duct work if outside the conditioned envelope

C. Control sunlight for heat - cool
   1. Adjustable awnings
   2. Eave extentions
   3. Color of shingles - siding

D. Use energy-efficient ancillary equipment
   1. Motors
   2. Blowers

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Recognize the important atmospheric factors that in combination determine human comfort.

(2) Be able to specifically define absolute and relative humidity in terms of the atmosphere.

(3) Be able to make interpretations and calculations in terms of the use of a Psychrometric Chart.

(4) Recognize mechanisms of thermal energy transfer needed to keep a human being at near optimum comfortable temperature.

(5) Identify the heat-producing mechanism in a human being and its exacting methods of temperature control.

(6) Identify human actions that are options for maintaining human comfort on an energy conservation basis.

(7) Be able to make wet and dry bulb measurements and determine relative humidity.

(8) Recognize the basics of sensible heat and latent heat in thermal processes.

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UNIT TITLES:

(1) The Comfort Zone

(2) Applied Psychrometrics

(3) Temperature, Humidity, and Air Control

(4) Energy Conservation Opportunities and Systems Options for Human Comfort

VOCABULARY:

Metabolic Processes
Wet Bulb Temperature
Dry Bulb Temperature
Comfort Zone
Latent Heat
Sensible Heat
Relative Humidity
Dew Point
Absolute Humidity
Ventilation
Evaporative Cooling
C.O.P.
Humidifier
Psychrometric Chart
Conditioned Air
Desiccant Utilization
Infiltration
Cross Ventilation
Thermal Stratification
Particulate Filter
Noxious Gases
Central Duct
Passive Solar Design
Zone Heating and Cooling
Air Quality
Heat Transfer Processes
Ion Precipitator
Color vs. Light Absorption
Air Movement Rate

Unit 1. Comfort Zone

- A. Thermal controls for human comfort

Reference 1, Chapter 1,2,3

  - 1. Examine space utilization
  - 2. Effects of clothing on comfort

Reference 2, Chapter 1

  - 3. Zone control for:
    - a. Relative humidity variations
    - b. Effective temperature range
    - c. Low energy demand areas
    - d. High energy demand areas
  - 4. Variants of activities
    - a. Residences
    - b. Commercial
    - c. Industrial
  - 5. Requirements for maintaining heat balance of the human body (metabolism vs. thermal loss)

Reference 3, pp. 328-335

    - a. Age variants
    - b. Activity variants

Unit 2. Applied Psychrometrics

- A. Humidity aspects in defining comfort conditions

Reference 3, pp. 328-335
pp. 336-347

  - 1. Absolute humidity
  - 2. Relative humidity
  - 3. Relative humidity vs. temperature change
  - 4. Dew point
  - 5. Wet and dry bulb temperature measurements
- B. The psychrometric chart
  - 1. Air sensible heat changes
  - 2. Latent heat of water vapor
  - 3. Enthalpy change of air
  - 4. Interpretation of the psychrometric chart
- C. Mechanisms of heat production and dissipation associated with the human organism (maintaining a constant body temperature)
  - 1. Metabolism
    - a. Sedentary state

- b. Active state
- c. Age variants
- d. Hypo- and Hyperthermia

Unit 3. Temperature, Humidity, and Air Control

- A. Temperature control mechanisms
  - 1. Natural and forced ventilation

Reference 5, pg. 80

  - 2. Passive design for heat gain or loss
  - 3. Back-up heating and air conditioning
- B. Humidity control mechanisms

Reference 1, Chapter 1,2,3

  - 1. Dehumidifying - humidifying
    - a. Moisture condensation
      - 1) Air conditioning
      - 2) Dehumidifying apparatus
    - b. Desiccant utilization
    - c. Humidifying by:

Reference 3, pp. 17-18
pp. 337 & 345

      - 1) Evaporative devices in duct
      - 2) Plants and humidifiers
    - d. The role of infiltrated air to humidity control
  - 2. Mechanisms of heat dissipation from the human organism (the Law of Conservation of Energy)

Reference 3, pp. 15-22

    - a. Radiation losses
    - b. Conduction losses
      - 1) Surface area vs. volume
      - 2) Peripheral vs. internal circulation
    - c. Convective and infiltration losses
    - d. Evaporation of water
    - e. The exhaled breath
- C. Air control (air movement)
  - 1. Natural circulation

Reference 5, pp. 80-87

    - a. Cross ventilation - prevailing wind

b. Thermal chimney
c. Ceiling height
d. Multi-level space - thermal stratification
2. Forced ventilation

Reference 3, pp. 336-348

a. Room fan in window
b. Central duct
c. Paddle fan
3. Filtration for duct and pollen control

Reference 3, pp. 328-335

a. Fiber filter
b. Ion Precipitator
4. Control of noxious gases
a. Infiltrative dilution

Reference 3, pp. 328-348

b. Chemical separation and removal
1) Nitrogen oxides
2) Carbon monoxide
3) Ozone
4) Hydro-carbons
5) Formaldehyde

Unit 4. Energy Conservation Opportunities
A. Temperature Control - Building

Reference 4, pp. 165-170

1. Use natural processes where and when possible
a. Passive design in building for heating and cooling needed
1) Color properties; utilize light for cooling - dark for heating

Reference 6, pp. 219-262

2) Natural ventilation
3) Keep it small, use zone heating
b. Utilize adjustable awning, curtains, windows tuned to seasonal weather changes
c. Human activity
1) Greater physical activity when cooler and light physical activity when warmer

2) Use minimum space for activity performed (zone control)

3) Use appropriate clothing for desired effects

B. Energy conservation associated with humidity control

Reference 3, pp. 96-97

1. Use natural processes when practical
    a. Ventilation options
    b. Plant transpiration
2. Use high C.O.P. air conditioning units
3. Use zone considerations in humidifying or dehumidifying situations

Reference 3, pg. 61

4. Use evaporative cooling when possible

Reference 4, pp. 165-170

5. Clothes dryer - vented or not vented
6. Use the out-of-doors when possible and reasonable to do so as an activity site

STUDENT ACTIVITY

Assignment:

Have students over a weekend do five various physical activities and rate the activities on a scale of 1 to 10 for metabolic rate.

STUDENT ACTIVITY

Assignment:

Have students during a week's vacation ask at least 15 people what is their most comfortable living room temperatures. Plot these results in terms of the ages of the people questioned.

STUDENT ACTIVITY

Assignment:

Have the students solve this problem using a psychrometric chart:

IF AIR AT A DRY BULB TEMPERATURE OF 80° AND A RELATIVE HUMIDITY OF 70 PERCENT IS COOLED TO 68°, WHAT WILL BE THE RELATIVE HUMIDITY OF THE AIR?

STUDENT ACTIVITY

Assignment:

Given: A dry bulb temperature reading of 75° F and a wet bulb temperature of 66° F, what is the relative humidity of the air?

STUDENT ACTIVITY

Assignment:

Have students heat about one cup of magnesium chloride gently for 20 minutes and then weigh accurately to within 0.1 gram. Place the dry magnesium chloride on a dish in the laboratory and let stand open to the air for 3 days and then weigh again and calculate the mass of moisture absorbed by the magnesium chloride desiccant.

STUDENT ACTIVITY

Assignment:

Have students place a tack upside down on the upper surface of the globe of a Van de Graff generator. Note the ion wind off the point of the tack when the charger is operating. Place a neutral pith ball attached to a string in this ion wind and note the fact that it becomes electrically charged. Compare the above act with a dust particle in the ion wind and how it could be electrically charged and subsequently removed from the air (an ion precipitator).

STUDENT ACTIVITY

Assignment:

Make two strips of cotton cloth 2 inches wide and 3 inches long, one white and one black. Compare two thermometers to see if their temperatures are the same when placed on a paper towel on the work desk; note any difference.

Wrap the black strip of cloth around the bulb of one thermometer and the white strip of cloth around the bulb of the second. Place both thermometers on a paper towel on the work bench. Wait 15 minutes in a well-lighted room, then read and record each thermometer. Which color cloth would be best for thermal comfort in the summer time?

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Calculate fuel efficiency for various types of heating systems.

(2) Calculate energy efficiency ratio for cooling systems.

(3) Compare cost effectiveness for various ventilating, heating, and cooling applications.

(4) Make maintenance schedule for HVAC systems.

(5) Make energy conservation recommendations for heating, cooling, and ventilating systems.

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UNIT TITLES:

(1) Heating Systems

(2) Cooling Systems

(3) Ventilation Systems

(4) Energy Conservation Opportunities

VOCABULARY:

Ambient Temperature
Btu
CFM
Compression
Dehumidifier
HVAC
Diurnal Cycle
Electronic Air Filter
Heat Exchanger
Evaporative Cooling
Condenser
Heat Gain
Heat Loss
Latent Heat
Evaporator
Thermal Lag
Ventilation Air
Infiltration
Peak Load
Space Heating
Manometer
Zone Heating
One Ton Air Conditioning
Heat Pump
Resistance Heating
Combustion Losses
Chimney Losses
EER
COP
Filter Resistance
Heating Load
Cooling Load
Freon
Cross Ventilation
Noxious Gases
Use Period
Atomizing Nozzle
Overhang
Static Pressure
Total Pressure
Velocity Pressure
Conservation of Energy

Unit 1. Heating Systems

	A. Sizing
Reference 3, Chapter 8	1. Output of furnace
	2. Load to be handled coldest month
Reference 1, Chapter 6	3. Zone or central
	B. Rated furnace efficiency
	1. Furnace rated fuel Btu input/hr.
	2. Furnace rated Btu output/hr.
	C. Fuel cost and pollution considerations
	1. Wood
	a. Availability
Reference 6, Chapter 6,7,13 & 14	b. Type
	c. Pollution (heavy)
	d. Cost/Btu
	2. Coal
	a. Grade (Btu/lb)
	b. Size
	c. Pollution (heavy)
	d. Cost/Btu
	3. Natural gas
	a. Availability
Reference 6, Chapter 6,7,13 & 14	b. Cost/Btu
	c. Light pollution
	4. Fuel oil
	a. Availability
	b. Cost/Btu
Reference 6, Chapter 6,13 & 14	c. Moderate pollution
	5. Electricity
	a. Cost/Btu
Reference 6, Chapter 8,13 & 14	b. Availability - peak load
	c. Pollution considerations
	6. Heat pumps
	D. Heating system efficiency
	1. Combustion losses
	a. Ignition
	b. Carburetion (air fuel mixture)
	2. Chimney losses (heat exchanger design)
Reference 4, Unit 4	3. Duct and distribution losses
Reference 3, Chapter 8	4. Electric - pure resistance
Reference 5, pg. 96	5. Heat pump COP
	6. Thermostat setting
Reference 5, pp. 546 & 610-622	7. Filter resistance

Unit 2. Cooling System

- A. Sizing
  - 1. Output of cooling unit
  - 2. Load to be handled

Reference 5, pp. 367-375

  - 3. Zone or central
- B. Rated performance
  - 1. Evaporative cooler
  - 2. EER of air conditioning unit
- C. Cooling system efficiency
  - 1. Duct and distribution

Reference 3, Chapter 8
Reference 2, Chapter 13

  - 2. Thermostat setting
  - 3. Filter resistance
  - 4. System cycling
  - 5. Optimum freon charge

Unit 3. Ventilation Systems

- A. Natural (passive)
  - 1. Open windows and screened doors

Reference 2, pp. 149-170

  - 2. Prevailing wind utilized
  - 3. Thermal chimneys
- B. Powered ventilation
  - 1. Central blower

Reference 5, pg. 375

  - 2. Room fans
  - 3. Ceiling paddle fans
- C. Air quality vs. ventilation
  - 1. Temperature control
  - 2. Humidity control

Reference 5, pp. 328-348

  - 3. Dust - pollen
  - 4. Noxious gases
  - 5. Oxygen availability

Unit 4. Energy Conservation Opportunities

- A. Diminish the load by:
  - 1. More insulation
    - a. Ceiling
    - b. Walls - windows

Reference 7, pp. 3-1 & 4-1

    - c. Floors
  - 2. Less infiltration during heating or cooling season

Reference 8, Chapter 3

  - 3. Greater use of solar passive design
  - 4. Develop good energy conservation habits
    - a. Thermostat settings
    - b. Zone use periods

5. Make more extensive use of ventilation for control of temperature, humidity, and air quality, less on active heating and cooling

Reference 8, Chapter 6

   a. New construction
   b. Remodeling

B. Use more efficient HVAC systems
   1. Use higher EER cooling units

Reference 4, Unit 4

   2. Use better insulated and tighter duct work
   3. Keep all fluid flow speeds near optimum

Reference 3, Chapter 8

   4. Use timers for no use periods
   5. Match system components
   6. Keep good maintenance schedule on all:
      a. Heating equipment

Reference 2, Chapter 13
Reference 1, Chapter 6,9 & 10
Reference 3, Chapter 8
Reference 5, pp. 722-728

         1) Furnace filters
         2) Nozzles
         3) Blowers
         4) Heat exchangers
         5) Dampers
         6) Pumps
         7) Thermostats
         8) Controls
         9) Appliances
      b. Cooling equipment
         1) Condensers
         2) Evaporators

Reference 5, pp. 667-680
pp. 737-742

         3) Thermostats
         4) Blowers
         5) Filters
         6) Freon charge
         7) Controls

C. Utilizing special considerations
   1. Thermal effects associated with internal and external color of paints

Reference 9, pp. 225-258

   2. Attic ventilation
   3. Shrubbery effects
   4. Window area and location
   5. Living habits
   6. Educating the occupants on energy conservation
   7. Overhangs, awnings, movable insulation

STUDENT ACTIVITY

Assignment:

Examine the manufacturer's plate on your furnace at home. Record the fuel Btu/hr. burning rate for energy input and the Btu/hr. energy output of the furnace. What is the tested efficiency of that furnace? What is the fuel consumption rate in gal./hr., ft^3/hr., or kilowatts of your furnace?

STUDENT ACTIVITY

Assignment:

Research the Btu thermal rating of the fuels listed below (approximate)

A. Natural gas Btu/1000 ft^3

B. Propane Btu/lb.

C. Fuel oil No. 2 Btu/lb.

D. Soft coal Btu/lb.

E. Electricity Btu/KWH.

STUDENT ACTIVITY

Assignment:

A. Measure the dimensions of the hot air or cooling register in your laboratory.

L __________

W __________

Calculate its area in ft^2 __________

B. Using a water manometer in the register opening measure the following:

1. Static pressure __________
2. Total pressure __________
3. Velocity pressure __________

C. From the velocity pressure and an air flow chart (graph) determine the air speed exiting the register __________.

D. Calculate the air flow rate in ft^3 per minute from the register __________.

E. Measure the temperature of the air at the return air duct for the room. Calculate the Btu/min. exchanged in the room.

STUDENT ACTIVITY

Assignment:

List 4 major areas of neglect for HVAC energy conservation that could be easily corrected for major energy savings at your place of residence.

1. ________________
2. ________________
3. ________________
4. ________________

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify the main wave types making up the electromagnetic spectrum and where "visible light" is located within the spectrum.

(2) Identify the rainbow of color components making up the visible spectrum and what the three primary colors are.

(3) Recognize the major anatomical parts of the eye and the common theory of color vision.

(4) Distinguish the characteristics of incandescent and fluorescent light bulbs and fixtures.

(5) Determine lumen requirements and light bulb recommendations for various locations and task activities.

(6) Determine energy requirements needed for various illuminating considerations.

(7) Recognize the importance of natural lighting in application and design.

(8) Identify conservation options associated with illumination design and application.

(9) Know how a light meter works and how to utilize it.

REFERENCES:

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UNIT TITLES:

(1) Lighting Requirements

(2) Artificial Lighting Systems

(3) Natural Light

(4) Economic Aspects in Lighting

VOCABULARY:

Incandescent
Lumen
Watt
Foot Candle
Diffuse Reflection
Primary Colors
Fluorescent
Task Lighting
Absorption
Electromagnetic Wave
Infrared
Ultraviolet
Skylight
Phosphor
Ballast
Threshold Intensity
Solar Spectrum
Color Vision
Glare
Natural Lighting
Lighting Conservation
Light Meter
Mercury Vapor
Lumninous
Aesthetic Considerations
Clerestory

	Unit 1. Lighting Requirements
	A. The electromagnetic spectrum
	1. Visible light
Reference 8, Chapter 13	2. Colors that make up the visible spectrum
	3. Primary colors
	4. Basic components of man's optical system and current theory on color vision
	B. Location and task - activity lighting needs
Reference 5, pp. 371-372	1. Visual comfort - lighting intensity
	a. Reading
	b. Relaxing
	c. Sewing
Reference 2, pp. 5-1 Reference 1, pp. 5-8	2. Light meters, how they work and are utilized
Reference 3, pp. 266-267	3. Aesthetics
	4. Safety and code requirements
Reference 6, Chapter 9	5. Security applications
	6. Plant growth
	7. Thermal ramifications associated with light utilization
Reference 6, Chapter 14	8. Background color contributions
	9. Beam vs. diffuse lighting and shadow control
	Unit 2. Artificial Lighting Systems
	A. Incandescent illuminating systems
	1. Tungsten filament
	2. Mercury vapor
Reference 6, Chapter 14	3. Sodium vapor
	4. Spectrum considerations
	B. Fluorescent lighting
	1. Home
Reference 6, Chapter 14	2. Factory - school
	3. Spectrum considerations
	C. Mini applications
	1. Home
	2. Industry - commercial
	Unit 3. Natural Lighting
	A. Windows
	1. Size considerations
Reference 6, Chapters 9 & 14	2. Location effects
	3. Intensities and control
	4. Direct or diffuse

Reference 7, Chapter 10	B. Sky lights
Reference 6, Chapter 9	C. Open spaces
	Unit 4. Economic Aspects of Lighting
	A. Lighting efficiency
	1. Lumens per watt
Reference 2, pp 5-3, 5-5, & 5-6	a. Incandescent
	b. Fluorescent
	c. Mercury
	2. Bulb life
Reference 4, pp. 92-93	3. Dimmers
	4. Timers
	5. Wall finishes
	6. Task lighting
	7. Maintenance
	8. Shades - blinds
	B. Use more natural lighting
Reference 7, Chapter 10	1. Window size, type, and placement
Reference 6, Chapter 9	2. Planned activities

STUDENT ACTIVITY

Assignment:

1. Have the students take a narrow beam of a bright white light and pass it through a glass prism and note the spectral colors resulting. Which color is bent most and which is bent least? What electromagnetic waves lie at each of the visible parts of the electromagnetic spectrum?
2. Have students borrow a light meter used in photography and measure illumination intensities in at least a dozen different areas around a home. Record the results and bring to class for discussion.
3. Have students illustrate by taking photographs of the lighting effects produced by diffused light sources vs. small area bright beam sources. Note the shadow control associated with the utilization of large area diffuse lighting surfaces.

4. Have students demonstrate the absorbency and reflectivity associated with smooth surfaces that are painted different colors.

Procedure:

Take a bright beam of white light and measure its illuminating effect at a distance of 2 ft. with a light meter.

Using the same light source, aim it at about a 45° angle onto a red sheet of paper that is about one foot away. Aim the light meter at the red sheet of paper in line with the reflected beam at a distance of about one ft. and compare the results. About what percentage of the white beam of light was reflected and intercepted by the light meter?

Repeat the above using the following colors of paper:

Note the figure below.

Red __________

Orange __________

Yellow __________

Green __________

Blue __________

White __________

Black __________

(Record percent reflected into the light meter for each of the colors listed)

A = white light beam

B = light meter

C = various colors of art paper

STUDENT ACTIVITY

Assignment:

Given: A need exists for a design for natural lighting in a subterranean home that is to be constructed. Have students suggest a solution to the above, utilizing diagrams, etc., to support their positions.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Analyze the relationship between solar energy utilization and conservation.

(2) Suggest appropriate solar applications to enhance conservation in the home.

(3) Recognize unique solar applications and conservation opportunities available in new construction.

(4) Structure solar decisions associated with retrofit options.

(5) Recognize the range of many broad-based possibilities in utilizing solar energy in commercial and industrial applications.

(6) Recognize incentives available for solar system utilization.

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UNIT TITLES:

(1) Solar Incentives

(2) Solar Decisions in New Construction

(3) Solar Decisions - Retrofit

(4) Solar Decisions - Commercial and Industrial

VII-48 MODULE: CONSERVATION MEASURES AND SOLAR APPLICATIONS

VOCABULARY:

Active Solar System
Passive Solar System
Conservation
Direct Gain
Attached Sunspace
Retrofit
Pre-Heater
Heat Exchanger
Thermal Mass
Load Fraction
"Use Temperature"
Night Sky Radiation
Commercial Application
Building Orientation
Fluid Transport

Insolation Rate
Solar Incentives
Balance of Payments
Roof Ponding
Absorption Cooling
Clerestory
Solar Chimney
Aesthetics
Sun Rights
DHW Load
Degree Days
Utility Rebate
Process Heat
Solar Window

	Unit 1. Solar Incentives
	A. Tax incentives and rebates
	1. Federal
Reference 1, Chapter 3	2. State
	3. Local
	4. Utility rebates
	B. Real estate value
	C. Conservation
Reference 2, Chapter 3	D. Pollution control
	E. Economic considerations
Reference 2, Chapter 6	F. Other incentives
	1. Jobs locally
	2. National security
	3. Balance of payments
	G. Areas of solar utilization
	1. Active heating
Reference 4, Chapter 2	a. Liquid
	b. Air
	2. Passive heating
	a. Direct gain
Reference 3, Chapter 3	b. Indirect gain
	c. Isolate gain
	d. Roof ponding
	3. Ventilation
	a. Siting
Reference 1, Section 3	b. Window placement
	c. Solar chimney
	4. Cooling
	a. Night sky radiation
	b. Roof ponds
	c. Absorption cooling
Reference 5, Chapter 5	d. P.V. powered paddle fans ad attic blowers
	5. Water heating
	a. DHW
Reference 5, Chapters 3 & 4	b. Space heating
	c. Swimming pools
Reference 6, Chapter 6	d. Commercial applications
	6. Natural lighting
	a. Windows
Reference 3, pp. 118-124	b. Clerestories
	c. Skylights
	Unit 2. Solar Decisions in New Construction
	A. Siting
Reference 4, Chapter 8	1. Sun rights
	2. Zoning regulations
Reference 1, Section 1	3. Building orientation
	4. Roofing style - pitch
Reference 5, Chapter 8	5. Solar window
	6. Future obstructions

	7. Landscaping and terrain
Reference 6, Chapter 7	8. Heating and cooling degree days
	9. Seasonal insolation rates
	B. System options
	1. Active
	a. DHW
Reference 5, Chapter 4	b. Space
	c. Other
	2. Passive
	a. DHW
Reference 5, Chapter 3	b. Space
	c. Other
	C. Economic considerations
	1. Cost
Reference 2, Chapters 6 & 7	2. Financing
Reference 1, Section 1 & 3	3. Pay back
	4. Load fraction carried
	5. Future projections
	D. Planning for future retrofit
	1. Heating/cooling system
	2. Storage
	a. Type
	b. Space requirements
	3. Collector
	a. Type
	b. Requirements
	1) Mounting
	2) Orientation
	3) Space
	4) Aesthetics
	4. Other requirements
	a. Piping - ducting
Reference 2, Chapters 11 & 12	b. Wiring
	Unit 3. Solar Decisions - Retrofit
	A. Survey
	1. Existing heating system
Reference 6, Chapters 6, 7 , & 8	2. Space heating load
	3. DHW load
Reference 6, Chapter 2 & 3	4. Building orientation
	5. Solar window
	6. Roof orientation and slope angle
	7. Indoor installation restrictions
	a. Pipe and duct availability
	b. Storage size and location

	8. Outdoor installation restrictions
	9. Determine system cost/ economics
Reference 6, Chapter 8	a. Type of system
	b. Location of system
	c. Rate energy savings
	Unit 4. Solar Decisions - Commercial and Industrial
	A. Energy costs
	1. Current
Reference 2, Chapter 1	2. Five year projection
Reference 7, Chapter 15	3. Availability factors
	B. Load considerations
	1. Space heating load determinations
Reference 6, Chapter 7 & 8	2. Hot water
	a. Demand vs. time
	b. "Use" temperature factors
Reference 2, Chapter 14	c. Percentage of load by solar
	d. Storage options
	e. Collector options
Reference 2, Chapter 11	f. Fluid transport type
Reference 6, Chapter 9	g. Control options
Reference 2, Chapter 17	
	C. Solar system costs
	1. Predicted performance
	2. Financing options
Reference 2, Chapter 6	3. Operating cost/month
	4. Maintenance cost/month
	5. Cost/Btu delivered over life of system
	D. Space requirements
	1. Internal
	2. External
	E. Aesthetic options
Reference 2, Chapter 9 Reference 2, Chapter 18	F. System reliability and back-up determination

STUDENT ACTIVITY

Assignment:

1. For an installed solar DHW system costing $2,300.00 locally, have students research:
   - A. Any local tax incentives.
   - B. State tax incentives.
   - C. Federal tax incentives.
   - D. Utility rebates available.

2. Obtain from a local solar DHW retailer and installer the product literature associated for a particular unit that is sold and determine the following:
   - A. Total cost of the installed system.
   - B. Itemized detail of solar incentives (in dollars and cents).
   - C. Sizing details.
   - D. Listing of major components.
   - E. Expected Btu/day performance.
   - F. Percentage of DHW load handled.
   - G. Show expected dollar savings per month from the installed system.

3. The student is to formulate a design for a new residential dwelling and incorporate at least (10) major conservation or solar options that will greatly contribute to energy efficiency in the space heating or DHW heating of the home.
   - A. The design plan should be neatly illustrated and scaled.
   - B. The design plan should consider site options.
   - C. Attached to the plan should be a listing of the 10 special features defining solar applications and conservation for energy efficiency in the home.

4. Have the students visit a large local restaurant and seek out from management the following:
   - A. Number of meals served per month.
   - B. Total utility bills
     - 1. Gas
     - 2. Electric.
   - C. Determine energy cost rate for each energy type: (cost/KWH) or (cost/ft^3 gas).
   - D. Hot water use per day (gal/day) average.
   - E. "Use" temperature of DHW.
   - F. Energy cost per meal.

G. Average temperature of the water coming into the restaurant from the well or city main.

5. Have the students take data from Part 4 and design a solar pre-heat system that includes determination of the following: (Installed cost rate to be 1,000 dollars/ 25,000 Btu/day for the pre-heat system).

   A. What load size is to be handled by the solar pre-heat system? (Btu/day) average

   B. Percentage of total load handled by solar.

   C. Thermal storage capacity (Btu/day).

   D. Restaurant thermal DHW load vs. time graph.

   E. Expected total cost of the pre-heat system.

   F. Diagram or sketch of the solar pre-heat system.

   G. List tax incentives possible.

   H. Dollars per day energy savings expected.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Comprehend the basic terminology used in describing basic solar or passive design concepts in building construction.

(2) Identify generic categories utilized in passive design approaches.

(3) Relate to and identify physical configurations associated with passive solar design approaches.

(4) Recognize and comprehend various details of architectural integration related to energy conservation and basic solar passive design concepts in residential construction.

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MODULE: PASSIVE SOLAR DESIGN APPROACHES

UNIT TITLES:

(1) Generic Categories

(2) Physical Configurations

(3) Architectural Integration

VOCABULARY:

Phase Change
Thermal Mass
Trombe Wall
Clerestory
Insolation Rate
Heating Load
Cooling Load
Protected Entrance
Micro Climate
Building Orientation
Insulation
R-Valve
Direct Gain
Isolate Gain
Insolate
Convection
Conduction
Radiation
Subterranean Construction
Desiccant Cooling
Aesthetics
Solar Azimuth
Solar Altitude
Humidity
Roof Pond
Sky Light
Greenhouse
South Eve
Solar Window
Heating Degree Day
Cooling Degree Day
Thermal Storage
Greenhouse Effect
Convective Loop
Thermal Chimney
Water Wall
Sun Chart
Sun Rights
Storm Windows
Condensation
Evaporation
Berming
Evaporative Cooling
Natural Ventilation
Landscaping
Adjustable Awnings
Interior Design
Exterior Insulation

Relative Humidity
Architect
Latent Heat
Lee Side
Vents
Wall to Floor Area Ratio
Interior Color Effects
Absorption
Air Infiltration
Wind Break
Air Film
Perimeter

	Unit 1. Generic Categories
	A. Some preliminaries (radiation)
	1. Source
Reference 3, pp. 5-18	2. Wavelength
	3. Solar constant
	4. Air mass vs. solar attenuation
Reference 7, Chapter 2	5. On horizontal surface
	6. On vertical surface
	7. Seasonal aspects vs. solar altitude
	8. Seasonal aspects vs. solar azimuth
	9. Determination of local solar time
Reference 3, pg. 558	10. On wall surface, a function of building orientation and design
	B. Apply energy conservation techniques first, by controlling heat loss or gain by:
Reference 8, pg. 5-6	1. Insulating the building envelope
Reference 7, Chapter 7	2. Controlling infiltration losses
Reference 2, pp. 4 & 25	3. Humidity management
Reference 3, pg. 265	4. Using natural ventilation as much as possible
	5. Utilizing thermal mass advantageously
	C. Direct gain (passive solar heating)
Reference 3, pg. 444	1. South wall monthly insolation rate
	2. North wall monthly insolation rate
	3. West wall monthly insolation rate
	4. East wall monthly insolation rate
	5. South wall glass
Reference 3, pp. 155-157	a. Glass area vs. living area in various climate conditions
	b. Glass area vs. thermal mass
Reference 9, pg. 203	c. Insulating factors
	6. South wall overhang
Reference 3, pp. 249-257	a. Summer
	b. Winter
	c. Latitude factors

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Reference 3, pp. 128-132 118-144	7. Clerestories and sky lights
	a. Insolation
	b. Insulation
	8. Thermal storage (concrete or water)
	a. Materials
	b. Thermal capacity
	c. Walls
	d. Floors
Reference 3, pp. 136-143	9. Thermal swing
	a. Storage
	b. Interior air
	c. Outside air
	D. Indirect gain (passive solar heating)
	1. Trombe wall
Reference 9, pg. 258	a. South wall glass vs. wall area
	b. Wall composition
	1) Concrete
Reference 3, pp. 145-153	2) Water
	3) Other
	c. Wall thickness
Reference 7, Chapter 5	d. Thermal storage capacity
	2. Attached greenhouse
Reference 8, pp. 22-48	a. Sizing
Reference 1, pg. 117	b. Moveable insulation
Reference 2, Chapter 3	c. Venting
	d. Thermal storage
Reference 1, pg. 105	3. Roof ponds
Reference 2, Chapter 3	a. Night heat
Reference 3, pp. 186-193	b. Day cooling
	E. Isolate gain (passive)
Reference 3, pg. 52	1. Detached greenhouse
Reference 1, pp. 115-153	2. Convective loop
	F. Passive solar cooling
Reference 8, pg. 69	1. Natural ventilation
Reference 1, pp. 163-169	2. Evaporative cooling
	3. Desiccant cooling
	4. Thermal chimney
Reference 2, Chapter 3	5. Building orientation and shape
Reference 9, pg. 56	6. Landscaping - shrubs
Reference 3, pp. 100-105	7. Window size and location
pp. 249-255 Reference 9, pg. 185	8. Adjustable awnings and vents
Reference 8, pp. 63-69 Reference 3, pg. 262	9. Indoor and outdoor color choices
Reference 4, pg. 100	10. Attic venting
Reference 2, pg. 127	11. Berming - subterranean construction
	12. Reflective film

	Unit 2. Physical Configurations
	A. Building location
	1. Solar access
Reference 9, pp. 41-70	2. Prevailing winds
	3. Terrain aspects
	B. Building shape
	1. Wall area vs. living area
Reference 9, pg. 367	2. Circular - options
	3. Multi-story - multi-unit considerations
	C. Building orientation
	1. East - west dimensioning
Reference 6, pp. 3-1 & 3-5	2. Protected north side - heat
	3. Exposed south side - heat
	4. Small east-west wall - cooling
	5. Prevailing winds
	D. Window size and location
Reference 9, pp. 258-287	1. Large glass area - south wall
	2. Small north window area - heat conservation
Reference 9, pp. 121-204	3. Small east and west wall window area for summer cooling
	4. Clerestory faces south
Reference 3, pp. 106-108	5. Prevailing winds - cross ventilation
	E. Earth - building - configurations
Reference 2, pg. 127	1. Berming
Reference 4, pp. 100-106	2. Cellars
	3. Subterranean
	F. Protected entrance
Reference 2, pg. 128	1. Double door
Reference 3, pp. 94-101	2. Foyer
	G. Interior design
	1. Location and venting of water heater
Reference 5, pg. 31	2. High use space
Reference 9, Chapter 6	a. Kitchen
	b. Living room
	3. Low use space
	a. Bedrooms
Reference 9, pg. 139-148	b. Storage
	c. Garage
	4. Closets on the exterior wall
Reference 2, pg. 133	5. Cross ventilation
Reference 9, Chapter 17 & 8	6. Color choices and wall surfaces

	H. External insulation
	I. External design
Reference 4, pg. 102	1. Roof structure
Reference 9, pp. 337-373	2. Color choices
Reference 4, pg. 105	3. Landscaping
	4. Elevation aspects
	5. Maintenance considerations
	Unit 3. Architectural Integration
	A. Utilization
	1. Zoned heating and cooling
	2. High - low use areas
Reference 9, pp. 355-364	3. Single or double story
	B. Aesthetics
Reference 9, Chapter 8 & 9	1. Indoor design
	2. Outdoor design
	C. Energy efficiency
Reference 6, pp. 7-2 through 7-10	1. Extra building costs
19-8 through 19-11	2. Percentage of load accommodated
	D. Maintainability
Reference 6, pp. 6-8 & 6-11	1. Maintenance and repair
	2. Replacement life

STUDENT ACTIVITY

Assignment:

1. Have the students list and define twenty design or construction features that contribute to good solar passive design for heating and cooling for a residential building.

2. Have the students make a site plan as well as a floor plan for a residential dwelling incorporating at least one dozen of the major features listed in Part 1.

3. Have the students sketch a detailed drawing illustrating each of the following concepts:
    1. Isolate gain.
    2. Cross ventilation.
    3. Thermal chimney.
    4. Seasonal effects on south eave.
    5. Trombe wall.
    6. Direct gain clerestory.
    7. Convective loop.

8. Building orientation.
9. Passive attic ventilation.

4. Have students list the major processes of each of the following:
    A. Passive heating.
    B. Passive cooling.
    C. Natural ventilation.

OBJECTIVES:

Upon completion of this module, the students should be able to:

(1) Identify important environmental considerations to be utilized in good passive design for buildings.

(2) Recognize user-imposed considerations in passive design structuring for building construction.

(3) Recognize legal considerations imposed by utilizing passive design concepts.

(4) Evaluate financial ramifications associated with passive design utilization in building construction.

(5) Identify clearly the advantages and disadvantages associated with the use of passive design concepts.

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UNIT TITLES:

(1) Environmental Considerations

(2) User-Imposed Considerations

(3) Legal and Financial Considerations

(4) Advantages and Disadvantages of Passive Design

VOCABULARY:

Insolation
Solar Altitude
Solar Azimuth
Heating Degree Day
Cooling Degree Day
Relative Humidity
Air Quality
Contract
Sun Rights
Zoning Restriction
Codes
Zone Heating and Cooling
Outdoor Design Temperature
Indoor Design Temperature

Solar Access
Use Tax
Self-Sufficiency
Conservation
Retrofit
Passive Design
Simple Payback
Inflation
High Use Area
Low Use Area
Environment
Legalities
Climate

	Unit 1. Environmental Considerations
	A. Insolation availability
	1. Winter
Reference 4, Chapter 2	a. Solar altitude (max and min)
Reference 11, Chapter 2	b. Solar azimuth (sunrise and sunset)
	c. Cloudiness factor
Reference 6, pg. 366	d. Average insolation rate on horizontal surface (in Btu/ft^2 day) coldest month, and the following:
	1) South wall average (Btu/ft^2 day)
	2) North wall average (Btu/ft^2 day)
Reference 6, pg. 444	3) East wall average (Btu/ft^2 day)
	4) West wall average (Btu/ft^2 day)
	2. Spring and fall
Reference 11, Chapter 2	a. Solar altitude (max and min)
	b. Solar azimuth (sunrise and sunset)
	c. Cloudiness factor
Reference 6, pg. 366	d. Average insolation rate on a horizontal surface (Btu/ft^2 day)
	3. Summer
Reference 11, Chapter 2	a. Solar altitude (max and min)
	b. Solar azimuth (sunrise and sunset)
	c. Cloudiness factor
Reference 6, pg. 366	d. Average insolation rate on a horizontal surface (Btu/ft^2 day) and the following:
	1) South wall average (Btu/ft^2 day)
Reference 2, pg. 21	2) North wall average (Btu/ft^2 day)

Reference 6, pg. 444	3) East wall average (Btu/ft^2 day)
	4) West wall average (Btu/ft^2 day)
	B. Temperature factors
	1. Winter
Reference 6, pg. 386	a. Average max temperature
	b. Average min temperature
Reference 6, pg. 436	c. Heating degree days (coldest mo.)
	d. Heating degree days (all winter)
	2. Spring
	a. Average max temperature
Reference 6, pg. 386	b. Average min temperature
	c. Heating degree days
Reference 6, pp. 436 & 443	d. Cooling degree days
	3. Summer
	a. Average max temperature
Reference 6, pp. 386 & 398	b. Average min temperature
	c. Cooling degree days (hottest month)
	d. Cooling degree days (all summer)
	4. Fall
	a. Average max temperature
Reference 6, pp. 386 & 398	b. Average min temperature
Reference 6, pg. 436	c. Heating degree days
	d. Cooling degree days
	C. Relative humidity
	1. Average relative humidity winter
	2. Average relative humidity spring
Reference 10, pg. 69	3. Average relative summer
	4. Average relative fall
	D. Wind conditions and rainfall
	1. Winter
Reference 2, pg. 23	a. Average speed
	b. Prevailing direction
Reference 1, Chapter 5	c. Inches rainfall
	2. Spring
	a. Average speed
Reference 1, Chapter 5	b. Prevailing direction

	c. Inches rainfall
	3. Summer
	a. Average speed
Reference 2, pg. 23	b. Prevailing direction
Reference 1, Chapter 5	c. Inches rainfall
	4. Fall
	a. Average speed
Reference 2, pg. 23	b. Prevailing direction
Reference 1, Chapter 5	c. Inches rainfall
	Unit 2. User-Imposed Considerations
	A. High use areas (kitchen, living room, den, bathroom) must have good control of:
Reference 2, pg. 21	1. Temperature
Reference 10, pg. 69	2. Humidity
Reference 2, pg. 22	3. Natural lighting
Reference 1, pg. 238	4. Air quality
	B. Moderate use areas (bedroom, foyers, hallways, closets) moderate control of:
	1. Temperature
Reference 4, Chapter 6	2. Humidity
Reference 2, pg. 22	3. Natural lighting
Reference 2, pg. 67	4. Air quality
	C. Low use areas (cellar, garage, storage areas) little control of:
	1. Temperature
Reference 2, pg. 67 & 22	2. Natural lighting
	3. Humidity
	Unit 3. Legal and Financial Considerations
	A. Legal
	1. Codes
Reference 1, Chapter 4	a. Local building codes
	b. State building codes
	2. Contracts
	a. Architects
Reference 5, Chapter 7	b. Contractors
	c. Subcontractors
	3. Sun rights
	a. Solar Access
Reference 5, Chapter 8	b. Uniform solar energy code
	4. Zoning restrictions
	a. Control population density
Reference 5, Chapter 8	b. Location of structures
	c. Height of structures
	d. Bulk of structures
	e. Aesthetic characteristics

	f. Property covenants
	1) Affirmative
Reference 5, Chapter 8	2) Restrictive
	5. Tax disincentives
	a. Use tax
Reference 5, Chapter 8	b. Increase tax assessment
	6. Warranty aspects
Reference 5, Chapter 8	a. Full or partial
	b. Manufacturer and installer
Reference 5, Chapter 8	7. Insurance ramifications
	B. Financial considerations
	1. Solar incentives
	a. Federal
	b. State
	c. Local
	d. Utility
	2. Cost factors for
Reference 10, pg. 45	a. New construction
Reference 5, Chapter 4	b. Retrofit
Reference 1, Chapter 3	c. Loan borrowing rates
	d. Projected inflation rate
Reference 3, Chapter 1	e. Projected fuel costs
	3. Fuel costs savings
Reference 4, Chapter 7	a. Annual load handled
Reference 3, Chapter 1	b. Fuel cost saved
Reference 6, pg. 298	c. Simple payback time
Reference 5, Chapter 9	4. Improved property value
	Unit 4. Advantages and Disadvantages of Passive Design
	A. Advantages
	1. Fuel cost savings
Reference 3, Chapter 6	2. Greater self-sufficiency
	a. Owner
	b. Country
	3. Better comfort conditions
Reference 7, pg. 80	
	4. Less pollution
Reference 8, Chapters 13 & 14	a. Air
	b. Water
	5. Provides very great potential for job opportunity in retrofitting millions of poorly designed buildings
	6. Lessens load for utilities
Reference 10, pp. 4-14	7. Conserves fossil fuels
	8. Affords great flexibility of design

Reference 4, Chapter 7

9. Involves no moving parts and is therefore long lasting with little maintenance required

Reference 9, pp. 100 & 130

10. Can be applied to any geographical location on Earth
11. Operating costs are small or none at all

B. Disadvantages of passive design

1. Passive design involves some out-of-the-ordinary cost factors in both new construction and in the retrofit market

Reference 5, Chapter 8

Reference 3, pp. 5-9 through 5-13

2. May involve legal restrictions of various sort and taxes
3. Requires more involved engineering and design effort than in ordinary construction
4. Removes part of the earnings base from utilities
5. Requires high front end costs

Reference 5, Chapter 4

6. Often difficult to apply on a retrofit basis

Reference 5, Chapter 5

7. Occupant should be knowledgeable about energy conservation for system to function well

STUDENT ACTIVITY

Assignment:

Have students research the clear day insolation penetrating a single pane of glass per square foot on June 21st in Atlanta, Georgia on:

__________ A. The south side of a house

__________ B. The north side of a house

__________ C. The east side of a house

__________ D. The west side of a house

that has no shading device covering it.

STUDENT ACTIVITY

Assignment:

From an old floor plan blue print of a residential dwelling, have students:

A. Color high, moderate, and low use areas of the home for quick identity.

B. Make recommendations on how zone heating and cooling could be applied.

C. Suggest several solar passive design adaptions that could be applied to the home.

STUDENT ACTIVITY

Assignment:

Discuss with students the importance of having climate data before any reasonable passive design features can be applied to the final planning of a structure. Have one of the students inquire at the weather bureau for the following data pertaining to the local geographical area:

A. Seasonal average temperature.

B. Seasonal average wind velocity.

C. Seasonal prevailing wind direction

D. Heating degree days.

E. Cooling degree days.

F. Relative humidity averages.

G. Seasonal percentage cloudiness factor.

STUDENT ACTIVITY

Assignment:

In reference to the data obtained for activity in previous STUDENT ACTIVITY, have students consider how each of the listed variables could be utilized in some passive design features.

Example: Heating degree days vs. ratio of south wall glass to living area.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify the characteristics that define a passive liquid solar system and an active solar system.

(2) Recognize the conditions of application that would make a thermosiphon liquid system practical.

(3) Discuss the basic differences between a passive air system vs. an active air system.

(4) Identify mechanisms of heat exchange for air or liquid systems.

(5) Recognize storage differences commonly associated with liquid and air active and passive solar systems.

(6) Recognize options available for retrofit on an existing structure for active and or passive solar application.

(7) Identify advantages and disadvantages of a liquid vs. air type solar system.

(8) Recognize possible applications of both passive and active solar utilization.

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UNIT TITLES:

(1) Passive - Active Liquid Systems

(2) Passive - Active Air Systems

(3) Factors Affecting the System Choice

(4) Passive - Active Retrofit

VOCABULARY:

Thermal Storage
Sensible Heat
Latent Heat
Hybrid System
Active System
Passive System
Thermosiphon System
Fluid
Thermostat
Differential Controller
Condense
Evaporate
Infiltration
Ventilation
Duct
Motorized Damper
Adjustable Vents
Insolation Rate
Eave Considerations
Solar Azimuth
Plumbing Design
Solar Facing Window
Convection Current
Site Conditions
Building Orientation
Building Shape
Air Collector
Specific Heat
Heat Capacity
Fan Coil
Heat Exchanger
Change of Phase
Thermal Mass
Exterior Insulation
Aesthetic Effects
Degree Day
Heat Distribution
Movable Insulation
Solar Altitude

	Unit 1. Passive - Active Liquid Systems
	A. Basic components - passive - space heat or DHW
Reference 4, pg. 55	1. Solar collectors
	a. Liquid (flat plate)
	b. Liquid (concentrating collector)
Reference 2, Module 7	c. Roof pond
	2. Thermal storage
Reference 2, Module 6	a. Water tank (above level of collector)
Reference 10, pg. 66	b. Roof pond
	3. Distribution
	a. Conduction - air convection
Reference 2, Module 8	b. Radiation
	c. Water to air exchanger (active)
	B. Basic components - active
	1. Collector
Reference 11, Chapter 4	a. Liquid flat plate
Reference 4, pg. 71	b. Liquid concentrator
	2. Fluid circulant (energy transport)
Reference 2, Module 8	a. Water direct circulant (open), no exchanger
	b. Water - glycol closed single loop (internal)
	c. Water - glycol closed double loop (external)
	3. Storage
Reference 4, pg. 77	a. Water
Reference 11, Chapter 5	b. Phase change material
Reference 2, Module 7	c. Combination of the above
	d. Thermal mass (concrete slab)
	4. Distribution
	a. Tank to fan coil (water to air exchanger)
	b. Tank to slab and slab to air
	c. Tank to DHW
	C. Total load determination
Reference 11, Chapter 8	1. Space heating
	2. DHW
	a. 20 gal/day person for first two

b. 15 gal/day person beyond two

D. Percentage of thermal load to be handled by solar (coldest month)

Refer to Module II
Reference 11, Chapter 8

1. Space heating
2. DHW
3. Total load

E. Sizing considerations

1. Collector area vs. load (assume 40 percent efficiency)
   a. Solar fraction vs. SA/L

Reference 2, Module 14

   b. Correction for tilt
   c. Correction for azimuth
   d. Exchanger correction
   e. Total area needed
2. Collector area vs. storage (approximations)

Reference 2, Module 6

   a. 2 gal water storage vs. 1 ft^2 collector
   b. The equivalent of (3) times the ft^3 of water used if utilizing concrete

F. Control

1. Automatic (thermosiphon) (collector to storage)

Reference 2, Module 11

2. Differential controller (collector to storage)
3. Thermostat (storage to load)

Unit 2. Passive - Active Air Systems

A. Basic components (passive or active air)

1. Solar collectors

Reference 4, Chapter 1

   a. South-oriented, south wall windows

Reference 6, pp. 118 & 444

   b. Clerestories
   c. Skylights
   d. Solar flat plate air collectors
   e. Solar concentrating air collectors

Reference 1, pg. 288

   f. Greenhouse or sunspace
2. Thermal storage

Reference 9, pg. 56

   a. Rock bed
   b. Concrete wall

Reference 2, Module 6

   c. Water wall

Reference 4, pg. 97

Reference 1, pg. 171
Reference 2, Module 3

Reference 4, pg. 83

Reference 2, Module 13

Reference Unit 1

Reference 2, Module 14

Reference 6, pg. 118

        - d. Slab
        - e. Building mass
    - 3. Distribution
        - a. Air convection
        - b. Radiation of thermal mass
        - c. Forced ventilation
        - d. Combinations of the above
- B. Total load determination
    - 1. Space heating
    - 2. DHW preheat
- C. Percentage of load handled by solar
    - 1. Space heating, Btu/day
    - 2. DHW preheat, Btu/day
- D. Sizing considerations
    - 1. (Active) Collector area needed vs. load
        - a. Solar fraction vs. SA/L
        - b. Correction for collector tilt
        - c. Correction for collector azimuth
        - d. Exchanger correction (if any)
        - e. Total collector area needed
    - 2. (Passive) South facing glass (double pane) (assuming well-insulated building)
        - a. Cold climate (20° - 30° F average winter temperature) 0.19 to 0.38 south-facing glass per ft^2 living area
        - b. Temperature climate (35° to 45° F average winter temperature) 0.11 to 0.25 ft^2 south-facing glass per ft^2 living area
        - c. Warm climate (50° - 65° average winter temperature) less than 0.11 ft^2 glass per ft^2 living area

Reference 6, pp. 172 & 208

3. Sizing the greenhouse or sunspace (greenhouse adjacent to house along the south wall)
    a. Cold climates (average temperature 20° - 30° F in winter) 0.9 to 1.5 ft^2 greenhouse south-facing, double glass per ft^2 of living area

Reference 10. pg. 52

    b. Temperature climate (average temperature 35° - 45° F in winter) 0.53 to 0.9 ft^2 greenhouse south-facing, double glass per ft^2 of living area

E. Sizing the thermal storage to collector area

Reference 2, Module 6

1. Active air system For every 5 ft^2 of collector area, there should be 3 ft^3 of rock storage
2. Passive air

Reference 6, pg. 152

    a. Cold climate (20° - 30° F winter average) Use 0.72 to > 1.0 ft^2 of masonry wall 18 inches thick for one ft^2 of living area

Reference 6, pg. 152

    b. Temperature climate (35° - 45° F winter average) Use 0.35 to 0.6 ft^2 masonry wall 18 inches thick per one ft^2 living area

F. Control

Reference 2, Module 11

1. Active
    a. Collector to storage - differential control

Reference 7, pg. 59

    b. Collector to load - thermostat

	c. Thermostat control - blowers
	2. Passive
	a. Thermostat control vents, moveable insulation
	b. Manual control moveable insulation
Reference 9, pg. 57	c. Timers control vents and moveable insulation
	Unit 3. Factors Affecting the System Choices
	A. Site considerations
	1. Terrain
Reference 1, pg. 43	a. Hills (passive liquid)
	b. Flat (active)
	2. Solar access
	a. Ground (passive)
	b. Roof top (active)
	3. Temperature ranges (seasonal) and wind considerations
Reference 10, pg. 6	a. Non-freezing conditions (liquid)
	b. Freezing conditions (air)
	c. Heating degree days
	4. Landscaping effects
	B. Building structure
	1. Roof design
Reference 10, pg. 41	2. Interior design
	a. Active
	b. Passive
Reference 6, pg. 43	3. Thermal mass (passive)
Reference 6, pg. 444	4. Glazing area and orientation
	5. Degree insulated, internal or external
Reference 6, pg. 115	6. Materials of construction
	C. Cost of system vs. performance
	1. Passive vs. active
Reference 2, Module 15	2. Liquid vs. air
	3. Availability of retailer and installer
	4. Brand-name or otherwise
	D. Operating costs
Reference 1, pg. 121	1. Monthly
Reference 5, Chapter 9	2. Annual
	E. Maintenance and repair costs

	1. Service availability
Reference 2, Module 15	2. Equipment maintenance and repair needs
	a. Lubrication
Reference 3, Chapter 11	b. Filters
	3. Warranty considerations
	a. Installation
	b. Components
	1) Full
	2) Partial
	F. Use considerations of systems due to occupancy variables
	1. Constant
	2. Sporadic
Reference 5, Chapter 5	3. Non owner occupant (knowledgeable of system)
	4. Use patterns
	G. Simple payback period
	1. Financial incentives
Reference 9, pg. 43	a. Tax credit (Federal, state, local)
Reference 2, Module 15	b. Utility rebate
	2. Fuel cost savings
Reference 8, Chapters 8 & 15	a. Current
Reference 10, pg. 45	b. Projected
	3. Borrowing costs
	4. Inflation rate
	5. Property improvements
	H. Legalities
	1. Permits
Reference 1, pg. 31	2. Zoning restrictions
Reference 5, Chapters 7 & 8 Reference 9, pg. 127	3. Owner or contractor installed
Reference 4, pg. 135	I. Aesthetic considerations
	Unit 4. Passive - Active - Retrofit
	A. Site conditions
Reference 4, pg. 168	1. Solar access - seasonal details
Reference 1, pg. 43	2. Terrain considerations (hill or flat)
	3. Heating degree days at that site
Reference 10, pp. 35 & 6	4. Building space availability along the south wall

	B. Building
Reference 2, Module 18	1. Orientation (longest dimension)
	2. Shape
Reference 6, pg. 78	3. Height - single - double story
	4. Construction type
Reference 6, pg. 115	a. Brick
	b. Frame
	c. Block
	d. Floor (concrete - wood)
	5. Interior design - use areas
Reference 2, Module 17	a. Living area
	b. Storage area
	c. Attic size and height
	d. Garage
	e. Vacant areas
	f. Hallways
	g. Duct ways
	6. Exterior design
Reference 6, pg. 118	a. Roof structure and shape
Reference 7, pg. 63	b. Interior or exterior insulation and how well
	c. Window sizes and location
	7. Age and condition
	8. Type of existing heating system now installed
Reference 3, Chapter 15	9. Kind of back up to be used
	C. Cost vs. performance of each system
Reference 2, Module 21	1. Active
	2. Passive
	D. Durability of system - warranty aspects
	E. Enhanced property value - aesthetics
	F. Financial incentives
	1. Tax
Reference 2, Module 20	2. Utility
	G. Installation details
Reference 3, Chapter 21	1. Components
	2. Labor
Reference 2, Module 19	3. Scheduling
	H. Operating and replacement costs

STUDENT ACTIVITY

Discussion:

Have students list advantages and disadvantages of:

A. Passive solar DHW system.

B. Active solar DHW system.

STUDENT ACTIVITY

Assignment:

Have students design an active solar space heating system using liquid transport, illustrating in the design diagram:

A. Collector area and type.

B. Fraction of load to be handled and total load.

C. Fluid used for energy transport.

D. Storage type and thermal size.

E. Plumbing for:

  1. Collector to storage

  2. Storage to load.

F. Control for:

  1. Collector to storage

  2. Storage to Load.

STUDENT ACTIVITY

Assignment:

Have students list and briefly explain 20 different conservation or solar passive design features that they would want to utilize in building a new home.

STUDENT ACTIVITY

Assignment:

Problem: Given an operating solar hot air system used in handling part of the heating load.

Given: System Operates:

6 hours per day (sunny day)

Average Δ T across the collector = 25° F

Flow rate through the collector = 300 ft^3/min.

Density of air 13.4 $\frac{ft^3}{lb}$

Specific heat of air approximately 0.24 Btu/lb degree

Calculate: the performance of the system in Btu/day.

ENERGY CONSERVATION AND PASSIVE DESIGN

Representative Pre-Tests and Post-Tests

COURSE PRE-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Of the primary energy use segments __________ of the total occurs in the building segment:

   a. one-fifth
   b. one-fourth
   c. one-third
   d. one-half

2. It is essential that __________ and __________ be controlled in the human body for both human comfort and survival:

   a. heat loss and heat gain
   b. food and water
   c. nutrition and blood circulation
   d. breathing and heart beat

3. The addition of storm windows over single-pane windows can reduce heat loss by __________ percent:

   a. 5-10
   b. 10-20
   c. 20-30
   d. 40-60

4. __________ percent of the total U. S. energy budget is devoted to heating and cooling:

   a. 5.2
   b. 10.4
   c. 15.7
   d. 25.6

5. The cost of heated water constitutes approximately __________ percent of the annual home energy bill:

   a. 15
   b. 25
   c. 45
   d. 55

6. The average home uses over __________ kilowatts of electricity each year for lighting:

   a. 100
   b. 1000
   c. 1500
   d. 2000

7. The best way of using the sun for heating is to design and use a building as __________:

   a. an underground shelter
   b. a natural solar collector
   c. an agricultural drying unit
   d. none of the above

8. The __________ is a very simple and frequently used passive design concept requiring only large south-facing windows and some sort of thermal mass in the living space:

   a. direct gain system
   b. indirect gain system
   c. attached sunspace system
   d. isolated gain system

9. The human body acquires thermal energy from __________:

   a. water
   b. minerals
   c. foods
   d. all of the above

10. The average amount of glazing found in most homes is __________ percent of the floor area:

    a. 15
    b. 25
    c. 35
    d. 50

11. Indoor air comfort conditions can be changed by __________:

    a. treating the air supply
    b. changing filters
    c. changing clothes
    d. putting on more clothes

12. In solar domestic hot water draindown systems, protecting the system from freezing is dependent on __________:

    a. the city water pressure
    b. successful operation of solenoid valves
    c. an auxiliary heating element
    d. antifreeze mixture in the collector loop

13. An appliance with a wattage rating of 1000 uses __________ kwh of electricity for every hour it is in operation:

    a. 1
    b. 2
    c. 3
    d. 4

14. Generally, for a passive solar thermal storage wall, the thermal analysis of most concern is with cyclic oscillations which have a period of __________:

    a. 6 hours
    b. 12 hours
    c. 18 hours
    d. 24 hours

15. Energy conservation refers to practices and measures that __________ with which energy is used in all sectors of the economy:

    a. restrict the demand
    b. increase the efficiency
    c. regulate the ways
    d. ration the activities

16. The size or surface area of a passive solar thermal storage wall is not dependent upon which of the following:

    a. climate
    b. latitude
    c. sunspace
    d. space heat loss

17. An R-value of __________ is usually recommended for ceiling insulation in the far northern states:

    a. 10
    b. 20
    c. 30
    d. 40

18. Of the three general categories of space cooling methods for residential buildings, solar energy is only directly useful in __________:

    a. refrigeration methods
    b. evaporative cooling
    c. radiative cooling
    d. chemical reaction devices

19. The two major uses of appliances in the home, after heating and cooling, and hot water, are for __________ and __________:

    a. refrigeration and cooking
    b. disposals and dryers
    c. radio and television
    d. can openers and knife sharpeners

20. Combining __________ and __________ features of solar heating eliminates the problem of separated room heating:

a. direct gain and indirect gain
b. greenhouse and indirect gain
c. thermosiphoning and greenhouse
d. active and passive

ANSWERS TO COURSE PRE-TEST

1. c. one-third
2. a. heat loss and heat gain
3. d. 40-60
4. c. 15.7
5. b. 25
6. d. 2000
7. b. a natural solar collector
8. a. direct gain system
9. c. foods
10. a. 15
11. a. treating the air supply
12. b. successful operation of solenoid valves
13. a. 1
14. d. 24 hours
15. b. increase the efficiency
16. c. sunspace
17. c. 30
18. a. refrigeration methods
19. a. refrigeration and cooking
20. d. active and passive

CONSERVATION AS AN ENERGY SOURCE

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. As we make the transition from petroleum to renewable energy sources, we cannot sustain rapid growth in energy use and must consider __________:

   a. developing new technologies
   b. rationing available energy supplies
   c. conservation as an energy source
   d. accelerated exploration for more fossil sources

2. Hydroelectric energy is a traditional energy source, but will supply only __________ of the total U. S. energy demand by the year 2000:

   a. 2.5%
   b. 2.8%
   c. 3.1%
   d. 3.5%

3. Of the primary energy use segments, __________ of the total use occurs in the building segment:

   a. one-fifth
   b. one-fourth
   c. one-third
   d. one-half

4. An effective __________ establishes and maintains an efficient balance between a building's annual functional energy requirements and its annual actual energy consumption:

   a. energy audit
   b. energy management program
   c. energy study
   d. building heat load analysis

5. Energy available for our use is only __________:

   a. based on fossil fuel reserves
   b. located at or near the surface of the earth
   c. limited to our production capability
   d. periodically in short supply

6. Due to the __________ of fossil-fuels throughout the world, profound economic and political issues are associated with energy use:

   a. high demand
   b. finite nature
   c. transportation difficulties
   d. unequal distribution

7. Energy conservation refers to practices and measures that __________ with which energy is used in all sectors of the economy:

   a. restrict the demand
   b. increase the efficiency
   c. regulate the ways
   d. ration the activities

8. An _________ begins with a detailed, step-by-step analysis of a building's energy-use factors and costs.

   a. energy study
   b. energy audit
   c. energy management program
   d. building heat load analysis

9. The total influx of solar radiation to the earth is calculated to be __________:

   a. 6.59×10^{15} Btu/hr
   b. 6.59×10^{16} Btu/hr
   c. 6.59×10^{17} Btu/hr
   d. 6.59×10^{18} Btu/hr

10. The residential and personal sector of the U. S. economy consumes __________ of the total annual energy consumption:

    a. 30%
    b. 35%
    c. 40%
    d. 45%

11. A major requirement for an energy study activity is that potential energy conservation opportunities be analyzed to account for __________ and __________ interrelationships between building loads and energy systems:

    a. electrical and mechanical
    b. demand and supply
    c. thermal and functional
    d. heating and hot water

12. Our energy use has gone through two major transitions from the mid 1800's with the dominant sources in each of three periods being __________, __________, and __________:

    a. hydro, oil and coal
    b. wood, coal and oil
    c. coal, oil and nuclear
    d. hydro, oil and nuclear

13. At the 1978 crude oil production rate of 8.5 million barrels per day, the U. S. supply of domestic oil would become exhausted in __________:

    a. 9 years
    b. 15 years
    c. 18 years
    d. 25 years

14. Annual energy consumption in the United States is projected to level off at about __________ by the end of the century:

    a. 400 million Btu per person
    b. 425 million Btu per person
    c. 450 million Btu per person
    d. 475 million Btu per person

15. Different buildings and spaces have different thermal conditioning requirements according to __________:

    a. occupancy and duration of stay
    b. size and volume
    c. room location and size
    d. use and ventilation

16. Most energy management programs are best designed and accomplished on the basis of specific __________:

    a. costs
    b. percentage reduction in demand
    c. design situations
    d. energy conservation goals

17. Production estimates for coal indicate that maximum production for this energy source will occur about __________; using the lowest reserve estimates:

    a. 2000
    b. 2050
    c. 2100
    d. 2150

18. Conservation is the sum of those measures which _________ save energy and are economically justifiable:

    a. simultaneously
    b. independently
    c. collectively
    d. uniquely

19. Light water nuclear reactors are capable of extracting only about 2% of the fission energy of natural uranium, but breeder reactors can recover as much as _________:

    a. 70%
    b. 50%
    c. 30%
    d. 10%

20. Useful energy applications fall into the three main categories of _________, _________ and _________:

    a. hydroelectric, fossil, and nuclear
    b. industrial, transportation and agricultural
    c. light, power and heat
    d. mechanical, chemical and electrical

ANSWERS TO POST-TEST

1. c. conservation as an energy source
2. c. 3.1%
3. c. one-third
4. b. energy management program
5. b. located at or near the surface of the earth
6. d. unequal distribution
7. b. increase the efficiency
8. a. energy study
9. c. 6.59×10^{17} Btu/hr
10. b. 35%
11. c. thermal and functional
12. b. wood, coal, and oil
13. a. 9-years
14. c. 45 million Btu per person
15. a. occupancy and duration of stay
16. d. energy conservation goals
17. c. 2100
18. a. simultaneously
19. a. 70%
20. c. light, power, and heat

ENERGY CONSERVATION AND HUMAN COMFORT

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. The total thermal heat of a body is measured in units called __________:

   a. clos
   b. Btu's
   c. microns
   d. degrees

2. The normal deep tissue temperature of the human body is __________:

   a. 98.0°F
   b. 98.3°F
   c. 98.6°F
   d. 99.0°F

3. Depending upon the type and quality of food ingested, __________ are required for its digestion by the human body and accompanying release of thermal energy:

   a. 1-2 hours
   b. 2-3 hours
   c. 3-4 hours
   d. 4-6 hours

4. By adopting different cold-weather and hot-weather styles of dress, people are able to vary the __________ of their clothing as well as the amount of exposed body surface:

   a. style
   b. clo value
   c. character
   d. amount

5. It is essential that __________ and __________ be controlled in the human body for both human comfort and survival:

   a. heat loss and heat gain
   b. food and water
   c. nutrition and blood circulation
   d. breathing and heart beat

6. The process of __________ results by individuals becoming seasonally or residentially accustomed to the climate and temperature:

   a. physical activity
   b. adaptation
   c. acclimatization
   d. aging

7. __________ is necessary if a worker is to achieve optimum production:

   a. Temperature comfort
   b. Human health
   c. Air conditioning
   d. Proper ventilation

8. When the __________ nearby windows, walls, floors, and ceilings are significantly different than a comfortable dry bulb temperature reading, one feels uncomfortable:

   a. air movement over
   b. infiltration through
   c. humidity on
   d. surface temperature of

9. The human body acquires thermal energy from __________:

   a. water
   b. minerals
   c. foods
   d. all of the above

10. Just as there are units of measurement for the effectiveness of building insulation, the thermal insulation value of clothing is measured in __________ units:

    a. Btu
    b. clo
    c. microns
    d. degrees

11. __________ is very effective in helping to cool the body in surrounding temperatures of 77°F to 95°F:

    a. Little or no air movement
    b. Moderate air movement
    c. High air movement
    d. All of the above

12. An increase in the breathing rate, a greater flow of blood to the skin, and a feeling of warmth that may become uncomfortable are body responses to __________:

    a. physical activities
    b. involuntary reflexes
    c. voluntary reflexes
    d. body heat storage

13. In humans, excess calories will be converted to __________:

    a. muscle tissue
    b. fat tissue
    c. bone structure
    d. all of the above

14. Most individuals will suffer convulsions if their body temperature rises to __________:

    a. 100-101°F
    b. 102-103°F
    c. 104-105°F
    d. 106-107°F

15. The foods which release their thermal energy the fastest are __________:

    a. carbohydrates
    b. proteins
    c. fatty foods
    d. vitamins

16. If people are exposed to prolonged __________ without compensation or treatment, the results will be dehydration, heat fatigue, loss of temperature, and finally death:

    a. periods of cold
    b. periods of heat
    c. excessive humidity levels
    d. excessively dry air levels

17. Excessive body heat can be reduced by __________:

    a. increasing evaporative cooling
    b. increasing air temperature
    c. increasing "clo" value of garments
    d. all of the above

18. Because body chilling and overheating is more likely to occur in __________ and __________, attention and assistance for human comfort must be given to both groups:

    a. men and women
    b. teenagers and young adults
    c. young children and older people
    d. all of the above

19. Body heat loss can be increased by wearing fewer clothes or by reducing the __________ and __________ below resting comfort levels:

    a. air humidity and air velocity
    b. dry bulb temperature and wet bulb temperature
    c. environment heat gain and environment heat loss
    d. all of the above

20. When either indoor or outdoor temperatures are between 65°F and 77°F, a relative humidity between __________ percent is preferred for comfort:

    a. 0-10
    b. 10-15
    c. 15-20
    d. 20-60

ENERGY CONSERVATION AND HUMAN COMFORT

ANSWERS TO POST-TEST

1. b. Btu's
2. c. 98.6°F
3. d. 4-6 hours
4. b. clo value
5. a. heat loss and heat gain
6. c. acclimatization
7. a. Temperature comfort
8. d. surface temperature
9. c. foods
10. b. clo
11. b. Moderate air movement
12. d. body heat storage
13. b. fat tissue
14. d. 106-107°F
15. a. carbohydrates
16. b. periods of heat
17. a. increasing evaporative cooling
18. c. young children and older people
19. b. dry bulb temperature and wet bulb temperature
20. d. 20-60

BUILDINGS AND ENERGY CONSERVATION

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. The biggest single influence on building heating energy consumption is __________:

   a. house design
   b. house location
   c. type of heating system
   d. the occupants

2. A single-pane window, with a typical U-factor of 1.13, has a heat loss that is more than __________ times greater than a wall having a typical U-factor of 0.10:

   a. 2
   b. 5
   c. 10
   d. 20

3. As much as __________ percent of the heat loss in a home is through the ceiling in winter:

   a. 25
   b. 50
   c. 75
   d. 85

4. The most durable caulking compounds are the __________:

   a. oil- or resin-based
   b. lates-, butyl-, or polyvinyl-based
   c. elastomeric
   d. silicone

5. The addition of storm windows over single-pane windows can reduce heat loss by __________ percent:

   a. 5-10
   b. 10-20
   c. 20-30
   d. 40-60

6. Openings in the ceiling of a building may be found __________ the ceiling material:

   a. around vent pipes penetrating
   b. anywhere there is a break in the continuity of
   c. around attic entrances through
   d. along building studs through

7. Chimneys and flues for fireplaces or wood stoves, and exhaust vents and fans in kitchens all present a special problem in regard to __________:

   a. infiltration energy loss
   b. air movement
   c. humidity levels
   d. temperature control

8. Lowering the wind velocity on a house can be done by placing wind barriers __________:

   a. next to the house
   b. to channel the wind pattern
   c. to create wind turbulence
   d. between the house and the prevailing winter winds

9. The average amount of glazing found in most homes is __________ percent of the floor area:

   a. 15
   b. 25
   c. 35
   d. 50

10. The most important factor to consider when determining the amount of insulation to install is __________:

   a. the climate
   b. the type of roof
   c. the heat loss per square foot
   d. the occupants

11. An energy conserving house may be defined as __________:

   a. one which is well insulated
   b. one which effectively employs conserving measures
   c. one which uses passive techniques
   d. one which has efficient heating equipment

12. Thermal shutters and curtains have been successfully employed on __________ and __________ windows to control thermal transport:

    a. the inside and the outside of
    b. active and passive
    c. new and retrofit
    d. none of the above

13. An R-value of __________ is usually recommended for ceiling insulation in the far northern states:

    a. 10
    b. 20
    c. 30
    d. 40

14. The K-factor is a conduction factor that tells how much heat energy will pass through a piece of insulating material __________:

    a. of a particular type
    b. of a specified thickness
    c. in a particular direction
    d. none of the above

15. For determining the heat loss for a slab-on-grade foundation, it is the __________ rather than __________ of the foundation that is important.

    a. exposed perimeter rather than slab surface area
    b. type of material rather than slab surface area
    c. ground temperature rather than slab surface area
    d. air temperature rather than slab surface area

16. The space between the frame of a door and the door jambs is maintained by __________ which permits an air infiltration opening to exist:

    a. design
    b. unintentional design details
    c. blocking
    d. building ventilation requirements

17. For most applications, there is little benefit to be gained by adding more than __________ inches of insulation:

    a. 2
    b. 4
    c. 6
    d. 8

18. An energy conscious house may be defined as one which __________:

    a. is predominately underground
    b. utilizes large amounts of insulation
    c. utilizes effectively energy conserving and passive methods
    d. none of the above

19. The U-factor is a universal factor for heat transmission because it applies to __________ rather than __________:

    a. heat loss rather than heat gain
    b. wall construction rather than specific materials
    c. measurements rather than calculations
    d. calculations rather than measurements

20. The process known as __________ can draw out large volumes of conditioned air which is then replaced by the unconditioned infiltration air.

    a. chimney effect
    b. channeling
    c. convective heat transfer
    d. radioactive heat transfer

BUILDINGS AND ENERGY CONSERVATION

ANSWERS TO POST-TEST

1. d. the occupants
2. c. 10
3. c. 75
4. c. elastomeric
5. d. 40-60
6. b. anywhere there is a break in the continuity
7. a. infiltration energy loss
8. d. between the house and the prevailing winter winds
9. a. 15
10. c. the heat loss per square foot
11. b. one which effectively employs conserving measures
12. a. the inside and the outside
13. c. 30
14. b. of a specified thickness
15. a. exposed perimeter rather than slab surface area
16. c. blocking
17. b. 4
18. c. utilizes effectively energy conserving and passive methods
19. b. wall construction rather than specific materials
20. a. chimney effect

HVAC AND ENERGY CONSERVATION

POST-TEST

Directions: Circle the answer or answers you believe to be correct:

1. __________ percent of the total U. S. energy budget is devoted to heating and cooling:

   a. 5.2
   b. 10.4
   c. 15.7
   d. 25.6

2. During the winter, a relative humidity of less than __________ percent makes the air feel dry and irritates the nose and throat:

   a. 30
   b. 40
   c. 50
   d. 60

3. Air conditioning system duct outlets __________:

   a. are never located in the room
   b. should never be round
   c. may be located near the top or bottom of the room
   d. should never be rectangular

4. One basic rule is to provide at least __________ of fresh air per person to provide enough oxygen and to remove carbon dioxide:

   a. 2 cfm
   b. 4 cfm
   c. 6 cfm
   d. 8 cfm

5. The output capacity of heating equipment should not be less than the calculated heating load, but it should exceed the calculated heating load by more than __________ percent:

   a. 15
   b. 25
   c. 35
   d. 50

6. As far as space heaters are concerned, __________ should be considered last because they are heavy users of energy:

   a. electric heaters
   b. coal heaters
   c. wood stoves
   d. natural gas stoves

7. Moisture in the conditioned air is controlled during the cooling process by __________:

   a. a humidifier in the system or in the room
   b. opening the windows
   c. closing the windows
   d. setting out pans of water

8. Collecting, storing and using solar energy requires the control of __________:

   a. air flow
   b. liquid flow
   c. both air and liquid flow
   d. storage heat exchangers

9. An advantage of electric heating over heating by natural gas is that __________:

   a. it is less expensive
   b. it does not require a flue
   c. it does not require a piping system
   d. it is not subject to leaks

10. Indoor air comfort conditions can be changed by __________:

    a. treating the air supply
    b. charging filters
    c. changing clothes
    d. putting on more clothes

11. A basic absorption refrigeration cycle functions properly because __________:

    a. it has no moving parts
    b. of the action and reaction between absorbent and refrigerant
    c. it is cylindrical
    d. it uses no heat

12. Of the three general categories of space cooling methods for residential buildings, solar energy is only directly useful in __________:

    a. refrigeration methods
    b. evaporative cooling
    c. radiative cooling
    d. chemical reaction devices

13. Electric baseboards have an efficiency approaching __________:

    a. 25%
    b. 50%
    c. 75%
    d. 100%

14. The design of the air supply duct __________:

    a. affects the distribution of the air
    b. does not affect air distribution
    c. adds moisture to the air
    d. lowers the temperature of the air

15. The unit in the refrigeration cycle in which the heat is rejected is the __________:

    a. evaporator
    b. condenser
    c. coil
    d. compressor

16. The efficiency of a heat pump is measured in terms of how much easier it is to _________ than to __________:

    a. evaporate than to condense
    b. heat than to cool
    c. expand gases than to compress gases
    d. pump heat energy than to generate it by conventional means

17. In the operation of electric furnaces, most of the heat loss occurs __________:

    a. through the flue
    b. through the duct system
    c. by radiation
    d. by conduction

18. The filter in an air conditioning system should always be located in __________:

    a. the attic
    b. the supply duct
    c. the return duct
    d. the garage

19. The energy efficiency ratio (EER) is equal to __________ divided by __________:

    a. the sensible heat divided by the latent heat
    b. the Btu rating divided by the input watts
    c. the input watts divided by the Btu rating
    d. the latent heat divided by the sensible heat

20. An effective use of the heat pump is in combination with solar energy where the solar energy collector supplies a much higher temperature to the heat pump and improves the __________ for winter operation:

    a. space heating
    b. electrical energy demand
    c. coefficient of performance
    d. use of auxiliary heating

HVAC AND ENERGY CONSERVATION

ANSWERS TO POST-TEST

1. c. 15.7
2. a. 30
3. c. may be located near the top or bottom of the room
4. b. 4 cfm
5. a. 15
6. a. electric heaters
7. c. closing the windows
8. c. both air and liquid flow
9. b. it does not require a flue
10. a. treating the air supply
11. b. of the action and reaction between absorbent and refrigerant
12. a. refrigeration methods
13. d. 100%
14. a. affects the distribution of the air
15. b. condenser
16. d. pump heat energy than to generate it by conventional means
17. a. through the flue
18. c. the return duct
19. b. the Btu rating divided by the input watts
20. c. coefficient of performance

WATER USE AND ENERGY CONSERVATION

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Energy used to heat water for domestic use is the __________ largest use of gas, electricity, and oil:

   a. second
   b. third
   c. fourth
   d. fifth

2. An electric water heater __________ heats water as quickly as gas:

   a. can
   b. cannot
   c. should be able to
   d. should not be able to

3. The Residential Conservation Service calls for installation and/or replacement of shower heads or faucets with devices to limit the maximum flow to __________:

   a. 2 gallons per minute
   b. 3 gallons per minute
   c. 4 gallons per minute
   d. 5 gallons per minute

4. In unheated spaces, domestic hot water pipes should be __________:

   a. checked periodically for leaks
   b. rerouted to heated spaces
   c. insulated to prevent excessive heat loss
   d. supported to prevent bending

5. The cost of heated water constitutes approximately __________ percent of the annual home energy bill:

   a. 15
   b. 25
   c. 45
   d. 55

6. In a typical household, heat loss through the tank walls accounts for approximately __________ percent of the energy consumed for heating the water:

   a. 10
   b. 15
   c. 25
   d. 50

7. Insulating gas-fired water heaters equipped with a pilot light and a vent damper could __________:

   a. lead to overheating
   b. be beneficial for energy conservation
   c. lead to excessive heat loss
   d. be accomplished readily

8. In solar domestic hot water draindown systems, protecting the system from freezing is dependent on __________:

   a. the city water pressure
   b. successful operation of solenoid values
   c. an auxiliary heating element
   d. antifreeze mixture in the collector loop

9. The average American family of four uses approximately __________ gallons of water a day for indoor use:

   a. 100
   b. 200
   c. 300
   d. 400

10. __________ percent of household water is used in the kitchen and laundry:

    a. 5
    b. 10
    c. 25
    d. 50

11. Simple batch-type passive solar water heaters work well on sunny days, but they can lose tremendous amounts of heat __________:

    a. by convection to the atmosphere
    b. during the night and on cloudy days
    c. by radiation to the atmosphere
    d. if not properly insulated

12. The proper mixture of additional air with combustion or exhaust gases is important in gas and oil-fired water heaters, to __________:

    a. assist in safe passage of combustion products to the outside
    b. assist in maintaining the combustion process
    c. improve the hot water heater efficiency
    d. keep the pilot light burning

13. The average American family of four uses approximately __________ gallons of heated water a day for indoor use:

    a. 15
    b. 25
    c. 55
    d. 75

14. The major user of cold water in the home is the __________:

    a. kitchen
    b. laundry
    c. water heater
    d. toilet

15. The effect of convective self-flow is generally termed the __________:

    a. natural convection process
    b. thermosiphon effect
    c. chimney effect
    d. none of the above

16. The drainback solar DHW system requires __________ between the storage tank and delivery to the hot water supply:

    a. a heat exchanger
    b. no barrier
    c. insulation
    d. a time delay

17. Water heater flues __________ be capped:

    a. should
    b. should not
    c. are required to
    d. are not required to

18. An aerator installed on the kitchen faucet __________ the volume of water flowing:

    a. has no effect on
    b. increases
    c. decreases
    d. interferes with

19. In solar air collection systems, the heated air blows over a large __________, through which the domestic water supply is being circulated:

    a. rock storage bed
    b. duct flow system
    c. solar collector
    d. air-to-liquid heat exchanger

20. The major advantage of a double-tank solar DHW System, when compared to a single-tank system, is that cooler liquids are brought to the collector, increasing __________:

    a. its operating efficiency
    b. its heating ability
    c. its fluid flow rate
    d. its radiative heat transfer

WATER USE AND ENERGY CONSERVATION

ANSWERS TO POST-TEST

1. a. second
2. b. cannot
3. b. 3 gallons per minute
4. c. insulated to prevent excessive heat loss
5. b. 25
6. c. 25
7. a. lead to overheating
8. b. successful operation of solenoid valves
9. c. 300
10. c. 25
11. b. during the night and on cloudy days
12. a. assist in safe passage of combustion products to the outside
13. d. 75
14. d. toilet
15. b. thermosiphon effect
16. a. a heat exchanger
17. a. should
18. c. decreases
19. d. air-to-liquid heat exchanger
20. a. its operating efficiency

ILLUMINATION, APPLIANCES AND ENERGY CONSERVATION

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Residences use about __________ percent of the energy used in the United States:

   a. 16
   b. 26
   c. 36
   d. 46

2. Americans represent approximately 6 percent of the total world population and consume __________ percent of the total energy consumed in the world:

   a. 10
   b. 13
   c. 23
   d. 33

3. Unless a dishwasher is used, a hot water temperature of __________ °F is usually adequate:

   a. 200
   b. 120
   c. 300
   d. 100

4. In your home there are probably more than __________ items which use energy:

   a. 10
   b. 15
   c. 25
   d. 50

5. The average home uses over __________ kilowatts of electricity each year for lighting:

   a. 100
   b. 1000
   c. 1500
   d. 2000

6. Approximately __________ percent of the homeowner's energy usage is to operate electrical home appliances:

   a. 1
   b. 4
   c. 6
   d. 8

7. Energy used in cooking meals can be reduced by using __________:

   a. the stove oven
   b. top burners
   c. microwave oven
   d. electric fryers

8. The most important energy-saving feature to look for in refrigerators is __________:

   a. insulation
   b. frost-free operation
   c. electric door heaters
   d. tight-fitting door gaskets

9. The unit of illumination is the __________:

   a. footcandle
   b. watt
   c. ohm
   d. volt

10. An appliance with a wattage rating of 1000 uses __________ kwh of electricity for every hour it is in operation:

    a. 1
    b. 2
    c. 3
    d. 4

11. When needing to purchase a gas oven or range, look for one with __________ instead of __________:

    a. good insulation instead of no insulation
    b. separate units instead of a single unit
    c. electronic ignition system instead of pilot lights
    d. small burners instead of large burners

12. If every dishwasher user in the country cut out just one load a week, almost __________ kwh of electricity could be saved every day:

    a. 20 million
    b. 15 million
    c. 10 million
    d. 5 million

13. Stores and factories usually have illumination levels of __________:

   a. 10
   b. 50
   c. 75
   d. 100

14. By multiplying the customer's cost of one __________ of electricity by the kwh of energy used per hour, the cost of one hours' operation can be determined.

   a. volt
   b. ohm
   c. kilowatt
   d. watt

15. The two major uses of appliances in the home, after heating and cooling, and hot water, are for __________ and __________:

   a. refrigeration and cooking
   b. disposals and dryers
   c. radio and television
   d. can openers and knife sharpeners

16. The timer on a clothes dryer should be set to coincide as closely as possible with __________:

   a. a one hour drying time
   b. a one-half hour drying time
   c. a corresponding washer cycle
   d. the actual amount of time required to dry the clothes

17. When one moves twice as far away from a source of light, only __________ as much light will be received.

   a. 1/2
   b. 3/4
   c. 1/4
   d. 1/8

18. The refrigerator should be set on __________:

   a. 33-34°F
   b. 38-40°F
   c. 45-50°F
   d. 40-55°F

19. If an incandescent light bulb is used, the cost of turning on the bulb is roughly equal to the cost of electricity used in __________:

   a. 1 minute
   b. 3 minutes
   c. 5 minutes
   d. 10 minutes

20. For each watt of lighting power used, about __________ Btu of heat energy must be removed:

    a. 1.2
    b. 2.3
    c. 3.4
    d. 4.5

ILLUMINATION, APPLIANCES AND ENERGY CONSERVATION

ANSWERS TO POST-TEST

1. b. 26
2. d. 33
3. b. 120
4. d. 50
5. d. 2000
6. d. 8
7. c. microwave oven
8. a. insulation
9. a. footcandle
10. a. 1
11. c. electronic ignition system instead of pilot lights
12. b. 15 million
13. d. 100
14. c. kilowatt
15. a. refrigeration and cooking
16. d. the actual amount of time required to dry the clothes
17. c. 1/4
18. b. 38-40°F
19. c. 5 minutes
20. c. 3.4

PASSIVE SOLAR DESIGN CONSIDERATIONS

POST-TEST

Directions: Circle the answer or answers you believe to be correct:

1. A house that is tuned to __________ may not have the same construction on all four sides to meet passive design criteria:

   a. the sun
   b. the wind
   c. the local climate
   d. the local terrain

2. The optimum __________ of a building is one which loses a minimum amount of heat in the winter and gains a minimum amount of heat in the summer:

   a. orientation
   b. shape
   c. construction
   d. use

3. Interior spaces can be supplied with much of their heating and lighting requirements by placing them __________ of the building:

   a. along the north face
   b. along the east face
   c. along the west face
   d. along the south face

4. By employing __________ a building's ability to absorb and release heat without varying much in room temperature can be increased:

   a. dense materials
   b. large south-facing windows
   c. clerestories
   d. skylights

5. The best way of using the sun for heating is to design and use a building as __________.

   a. an underground shelter
   b. a natural solar collector
   c. an agricultural drying unit
   d. none of the above

6. Windows can affect energy-using systems accounting for _________ of the energy consumed in buildings:

   a. one-fourth
   b. one-third
   c. one-half
   d. two-thirds

7. One important factor of importance for passive solar windows is that they must have a high resistance to _________:

   a. breakage
   b. all thermal loss mechanisms
   c. reduction in light transmission
   d. infiltration

8. Generally, for a thermal storage wall, the thermal analysis of most concern is with cyclic oscillations which have a period of _________:

   a. 6 hours
   b. 12 hours
   c. 18 hours
   d. 24 hours

9. There are two basic elements in every passive solar-heating system _________ and _________:

   a. south-facing glass and thermal mass
   b. convection and thermosiphoning
   c. south-facing glass and overhangs
   d. south-facing glass and shading devices

10. The ratio of solar heat gain of a fenestration to solar heat gain of a reference double strength glass is called the _________:

    a. solar heat gain factor
    b. monthly solar load ratio
    c. shading coefficient
    d. heat loss coefficient

11. The property of _________ of a wall is a measure of its ability to absorb and store heat during one part of a cycle and then to release heat back through the same surface during the second part of the cycle:

    a. monthly solar load ratio
    b. thermal admittance
    c. thermal conductance
    d. heat capacity

12. In order to function effectively in a passive solar heating role, and maximize beneficial heat gain, the window must be __________ to the incident solar spectrum.

    a. selective
    b. perpendicular
    c. non-reflective
    d. highly transparent

13. The amount of care taken in placing a building on a site with respect to open space and sun is __________ that can be made about a building:

    a. an unimportant consideration
    b. the single most important decision
    c. controlled by other decisions
    d. none of the above

14. To be effective as a heat storage element, a wall must have high __________ and __________:

    a. density and specific heat
    b. porosity and surface area
    c. thermal admittance and surface area
    d. thermal conductivity and heat capacity

15. The __________ is a dimensionless correlation parameter defined as the monthly solar energy absorbed on the thermal storage wall surface divided by the monthly building load:

    a. monthly solar load ratio
    b. solar heat gain factor
    c. shading coefficient
    d. heat loss coefficient

16. When possible, a building should be built into the south-facing slope and/or earth should be bermed against the north face to __________:

    a. make the optimum passive structure
    b. take advantage of ground temperature
    c. minimize the amount of exposed north wall
    d. provide summer cooling

17. With the location of a building on its site, the next important step for passive design is __________ of the building:

    a. to define the rough shape
    b. to layout the interior spaces
    c. select the construction materials
    d. provide wind breaks

18. The __________ is the solar heat gain through a reference glass for clear days when the latitude, date, and time are specified:

    a. monthly solar load ratio
    b. shading coefficient
    c. solar heat gain factor
    d. heat loss coefficient

19. Beyond an angle of __________ the solar transmission through window glass falls off markedly and most of the energy is reflected from the glazing surface:

    a. 45 degrees
    b. 60 degrees
    c. 75 degrees
    d. 90 degrees

20. It is the __________ which provides most of a single-glazed window's thermal resistance.

    a. surface layer of air
    b. chemical composition
    c. thickness
    d. window size

PASSIVE SOLAR DESIGN CONSIDERATIONS

ANSWERS TO POST-TEST

1. c. the local climate
2. b. shape
3. d. along the south face
4. a. dense materials
5. b. a natural solar collector
6. d. two-thirds
7. b. all thermal loss mechanisms
8. d. 24 hours
9. a. south-facing glass and thermal mass
10. c. shading coefficient
11. b. thermal admittance
12. d. highly transparent
13. b. the single most important decision
14. d. thermal conductivity and heat capacity
15. a. monthly solar load ratio
16. c. minimize the amount of exposed north wall
17. a. to define the rough shape
18. c. solar heat gain factor
19. b. 60 degrees
20. a. surface layer of air

PASSIVE SOLAR DESIGN APPROACHES

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Passive solar systems utilize __________ to collect, store and distribute energy.
    - a. no mechanical systems
    - b. a building's orientation
    - c. architectural elements
    - d. a building's shape

2. Without control considerations for a direct gain passive solar system, tremendous discomfort can occur due to __________ and __________:
    - a. winter heat losses and summer heat gains
    - b. winter heat gains and summer heat losses
    - c. convection and radiation
    - d. overheating and uneven temperature distribution

3. Masonry may need sunlight diffused over a large surface area, but __________ can absorb heat effectively even when its concentrated by a reflector:
    - a. pebble beds
    - b. water in containers
    - c. adobe
    - d. fused salts

4. A properly designed Trombe wall will have __________ provided to cool the south face and provide circulation of heat:
    - a. air channels
    - b. mechanical fans
    - c. light colored surfaces
    - d. vents

5. The __________ is a very simple and frequently used passive design concept requiring only large south-facing windows and some sort of thermal mass in the living space:
    - a. direct gain system
    - b. indirect gain system
    - c. attached sunspace system
    - d. isolated gain system

6. Openings that are designed primarily to admit solar energy into a space are referred to as __________:

   a. clerestories
   b. sawtooths
   c. solar windows
   d. skylights

7. When considering the control of heat distribution in a __________, it should be recognized that thermal transfer is rapid, due to convection, and radiant distribution to a living space is almost immediate:

   a. water thermal storage wall
   b. mass thermal storage wall
   c. double-pane window
   d. thermosiphoning system

8. The size or surface area of a thermal storage wall is not dependent upon which of the following __________:

   a. climate
   b. latitude
   c. sunspace
   d. space heat loss

9. The __________ operates essentially in the same manner as a thermal storage wall except that the space between the glazing is much larger and can be used.

   a. direct gain system
   b. indirect gain system
   c. attached sunspace system
   d. isolated gain system

10. The exact location and size of __________ depends upon design considerations such as sun angle, special views, natural lighting and space use:

   a. skylights
   b. window openings
   c. clerestories
   d. thermal mass

11. Distribution of solar heat from a roof pond is by __________, so proximity of the ceiling to the individual being warmed is important:

   a. radiation only
   b. convection only
   c. conduction only
   d. all of the above

12. Massive floors, walls, benches, rock beds, and covered pools of water can all provide effective solar heat storage for _________:

    a. direct gain systems
    b. an attached sunspace
    c. indirect gain systems
    d. isolate gain systems

13. In the __________ passive system, the collector and thermal storage are separate units connected by piping or ducting:

    a. direct gain
    b. indirect gain
    c. attached sunspace
    d. isolated gain

14. The __________ is a series of clerestories, one directly behind the other:

    a. skylight
    b. sawtooth
    c. solar window
    d. none of the above

15. The requirements for a sunspace passive solar building type center on the glazed collector space which must be both __________ from the living space:

    a. attached yet distinct
    b. attached but not distinct
    c. attached and insulated
    d. attached but not insulated

16. In a direct gain system a portion of the heat admitted into each space can be stored _________ for use during the evening hours.

    a. with difficulty
    b. with little difficulty
    c. in an interior water wall
    d. predominately

17. The most common variations in passive solar heating by direct gain are found in the __________ and __________ of the thermal storage mass:

    a. type and size
    b. materials and location
    c. size and shape
    d. orientation and shape

18. If a large and effective __________ is not included within the envelope of a passive solar building, it will simply overheat:

a. thermal storage mass
b. south-facing window
c. room
d. heat distribution path

19. Combining __________ and __________ features of solar heating eliminates the problem of separated room heating.

a. direct gain and indirect gain
b. greenhouse and indirect gain
c. thermosiphoning and greenhouse
d. active and passive

20. The heat absorbed into a Trombe wall during the day __________ the wall into the living spaces at night.

a. does not work its way through
b. works its way through
c. radiates heat from
d. permits convection from

PASSIVE SOLAR DESIGN APPROACHES

ANSWERS TO POST-TEST

1. c. architectural elements
2. a. winter heat losses and summer heat gains
3. b. water in containers
4. d. vents
5. a. direct gain system
6. c. solar windows
7. a. water thermal storage wall
8. c. sunspace
9. c. attached sunspace system
10. b. window openings
11. a. radiation only
12. b. an attached sunspace
13. d. isolated gain
14. b. sawtooth
15. a. attached yet distinct
16. c. in an interior water wall
17. b. materials and location
18. a. thermal storage mass
19. d. active and passive
20. b. works its way through

OPERATIONAL DIAGNOSIS OF RESIDENTIAL APPLICATIONS

Semester Hours Credit: 3
Lecture: 2
Lab: 3

Project Director: Charles G. Orsak, Jr.

Prime Author: Stephen Pomroy

Contributing Author: Everet W. Bolin

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OPERATIONAL DIAGNOSIS OF RESIDENTIAL APPLICATIONS VIII-3

INTRODUCTION:

Solar energy systems have well demonstrated their effectiveness at providing a viable solution to the problem of increasing energy costs. However, system problems and failures can preclude the use of systems. The need for knowledgeable and skilled service technicians will insure long life and good performance of these energy production systems.

RATIONALE:

This course seeks to bring together the ideas and directions necessary to achieve an adequate level of skills and knowledge in the successful trouble-shooting and repair of solar energy conversion systems.

COURSE DESCRIPTION:

The associate technician program prepares a person to (1) apply knowledge to science and mathematics extensively and render direct technical assistance to scientists and engineers engaged in solar energy research and experimentation; (2) design, plan, supervise, and assist in installation of both simple and complex solar systems and solar control systems; (3) supervise, or carry out, the operation, maintenance, and repair of simple and complex solar control systems; (4) design, plan, and estimate costs as a field representative or salesperson for a manufacturer or distributor of solar equipment; (5) prepare or interpret systems; and (6) work with and communicate with both the public and other employees regarding the entire field of solar energy. The one-year program prepares students to install and maintain solar equipment.

COURSE PREREQUISITES:

Sizing Design, and Retrofit.

OBJECTIVES:

Upon completion of this course the student should be able to:

(1) Successfully demonstrate the use of various trouble-shooting skills in the diagnosis of failed systems.

(2) Show proficiency in the use of data collection devices and analysis skills to determine level of system performance.

(3) Demonstrate the hand skills necessary to repair or replace problem equipment or systems.

(4) Prepare trouble-shooting charts addressing problems, possible causes, and recommended actions for bringing a system back on-line.

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MODULE: REVIEW OF SYSTEMS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe liquid and air system configurations for hot water, space heating, space cooling, pools, and spa heating.

(2) Identify and list specific components of liquid and air systems.

(3) Explain and trace through four common modes of operation of liquid and air space heating systems.

REFERENCES:

(1) Solaron Application Engineering Manual - Air Systems.

(2) Solaron Application Engineering Manual - Liquid Systems.

(3) Lennox JRT Phase I (Solar), Lennox Industries Inc., P.O. Box 400450, Dallas, Texas 75240, 1979.

(4) Fundamentals of Solar Heating, SMACNA, 8224 Old Court House Road, Vienna, Virginia 22180, 1978.

(5) Solar Heating & Cooling of Buildings, Sizing, Installation and Operation of Systems, Colorado State, Solar Energy Applications Laboratory, 1980 edition.

UNIT TITLES:

(1) Liquid Systems

(2) Air Systems

VOCABULARY:

Closed-Loop
Stratification
Open-Loop
Hydronic
Absorption
Rock-Bed
Rankine
Components

Configuration
Sensible
Layout
Latent
Temperature
Phase-Change
Pressure
Liquid

	Unit 1. Liquid Systems
Reference 1, 3, & 5	A. Configurations
	1. Solar domestic hot water
	a. Closed-loop systems
	b. Open-loop systems
Reference 4, pg. 7-1	2. Space heat
	a. Closed-loop
	b. Open-loop
	3. Pools and spas
	4. Space cooling
	a. Absorption
	b. Rankine
Reference 3 "Components"	B. Components
	1. Collector circuit
	2. Storage circuit
	3. Controls
	4. Distribution circuits
	C. Modes of operation
	1. Collector to space
	2. Collector to storage
Reference 3 "Operating Modes"	3. Storage to space
	4. Auxiliary support
	5. Purge of heat
	Unit 2. Air Systems
Reference 1	A. Configuration
	1. Solar domestic hot water
Reference 4, section 7	2. Space heat
	a. Single blower
	b. Double blower
	3. Space cooling
Reference 4, pg. 5-2	B. Components
	1. Collector circuit
	2. Storage circuit
	3. Controls
	4. Distribution circuit
	C. Modes of operation
	1. Collector to space
	2. Collector to storage
Reference 4, pg. 7-1	3. Storage to space
	4. Auxiliary support
	5. Purge of heat

STUDENT ACTIVITY

Exercise

Laboratory:

1. Liquid hot water systems:
    a. Trace the fluid and energy flow in a closed-loop system.
    b. List and identify the system components.
2. Liquid space heat system:
    a. Trace the fluid and energy flow in an open-loop system.
    b. List and identify the system components.
3. Air space heat system:
    a. Trace the air and energy flow in a two-fan system design.
    b. List and identify the system components.
    c. Identify the modes of operation.

MODULE: DIAGNOSTIC TROUBLESHOOTING METHODOLOGY VIII-11

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe and apply analysis procedures in identifying solar energy systems.

(2) Identify types of tests for determining system responsiveness.

(3) Display skills using methods and tools to trouble-shoot system failures.

(4) Formulate and utilize a diagnostic procedure chart.

(5) Collect, analyze, and evaluate data relative to the performance of live operating system.

REFERENCES:

(1) Hare, Jr., Van Court, *Systems Analysis: A Diagnostic Approach*, Harcourt, Brace and World, Inc., 1967.

(2) *Performance Monitoring of Solar Domestic Hot Water Systems*, National Workshop, December 4-5, 1980, National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

(3) *Solar Domestic Hot Water System Inspection and Performance Evaluation Handbook*, Draft, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

UNIT TITLES:

(1) Systems Analysis: A Diagnostic Approach

(2) Instrumentation

(3) Data Collection and Performance Evaluation

VOCABULARY:

Flow Chart

Reliability and Accuracy

Diagnosis

Procedure Chart

System Analysis

Response Time

Isolation

Problem Solving

Unit 1. System Analysis: A Diagnostic Approach

Reference 1, pp. 13 and 27

- A. System description
  - 1. Explain the need for system description
  - 2. Forms of description
    - a. Energy flow diagrams
    - b. Subsystem block diagrams
    - c. Narratives

Reference 1, Chapter 9

- B. Systems analysis
  - 1. What is it?
  - 2. How does it work?
  - 3. Does it work as predicted?
  - 4. Why does it fail to operate as specified?
  - 5. Can it be improved?
  - 6. What are the effects of modification?
- C. Describe how a logical investigation proceeds
  - 1. Identification of symptoms
  - 2. Inspection of system, subsystem, and components
  - 3. Measurements involving systems, subsystems, components
  - 4. Analysis of results to reach a conclusion
- D. Formulation of the basic procedure
  - 1. Symptoms grouping step
    - a. General symptoms group
    - b. Specific symptoms group
  - 2. Inspection step
    - a. Listening checks
    - b. Visual checks
    - c. Tactile checks
  - 3. Measurement step
    - a. Energy flows
    - b. Component values
  - 4. Analysis
    - a. Correlating data
      - 1. By time, date,
      - 2. By task, activity

- b. Evaluating
  - 1. Does system meet design expectations?
  - 2. Is data accurate?

Reference 1, pg. 241

- E. Testing - system responsiveness
  - 1. External testing - conditions surrounding system
    - a. General description
    - b. Problems with outside testing
  - 2. Inside testing - conditions within system
    - a. General description
    - b. Selection of points
    - c. Types of probes

Reference 1, pp. 259-269

- F. Troubleshooting methods
  - 1. Detection at a glance
  - 2. Signal tracing (isolation by elimination)
  - 3. Creating independence
  - 4. Intermittent failures
  - 5. Stress methods
  - 6. Guessing

Unit 2. Instrumentation

Refer to Reference 2, for Instrumentation Techniques, Tools, Objectives

- A. Instrument quality
  - 1. Reliability
  - 2. Precision
  - 3. Accuracy
  - 4. Resolution
  - 5. Calibration
- B. Temperature
  - 1. Applications
    - a. Compare fluid temperature to and from collector
    - b. Compare collector and storage temperature
    - c. Ambient
  - 2. Instruments
    - a. Direct reading thermometer
      - 1. Bimetallic
      - 2. Liquid filled
    - b. Electronic

Reference 2

C. Flow
  1. Applications
    a. Determine flow/no-flow conditions
    b. Determine rate of fluid movement
    c. Use in conjunction with temperature to determine quantity of heat transfer
  2. Instruments
    a. Sight glass
    b. Flow rate indicator - direct reading
    c. Btu meter
    d. Circuit setter

D. Electrical
  1. Applications
    a. Circuit continuity
    b. Sensor resistance
    c. Circuit voltage
    d. Power consumption
    e. Ground readings
  2. Instruments
    a. VOM
    b. Amp meter
    c. Watt hour meter
    d. CKT tester
    e. Neon lite tester

E. Time
  1. Applications
    a. Duration of activity
    b. Time dependent analysis of thermal performance
    c. Analysis of daily system cycle
  2. Instruments
    a. Clock
    b. Elapsed time meter

F. Pressure
  1. Applications
    a. Monitor closed system pressure
    b. Pressure differences across circuit setter
    c. Static pressure in both air and liquid systems

- 2. Instruments
  - a. U-tube manometer
    - 1. Water
    - 2. Mercury
  - b. Inclined manometer
  - c. Bourbon tube

Reference 2

- G. Humidity
  - 1. Applications
    - a. Determine comfort level on psychrometric chart
    - b. Outdoor humidity
  - 2. Instruments
    - a. Humidity meter
    - b. Sling psychrometer
- H. Linear measurements
  - 1. Applications
    - a. Determine length
    - b. Area
    - c. Volume
  - 2. Instrument
    - a. Rule
    - b. Tape
- I. Insolation
  - 1. Applications
    - a. Total solar radiation
    - b. Direct solar radiation available
    - c. Diffuse solar radiation available
  - 2. Instruments
    - a. Btu meter
    - b. Pyranometer
    - c. Pyrheliometer
- J. Chemistry
  - 1. Applications
    - a. Determine acidity of transfer fluid
    - b. Determine anti-corrosion inhibitor level
    - c. Water hardness
  - 2. Instruments
    - a. Litmus paper
    - b. Inhibitor level test from supplier
    - c. Local agencies for water hardness

Unit 3. Data Collection: Performance Evaluation

Reference 3, Appendix B

A. Equipment
  1. Thermometer
  2. Solar radiation meter
  3. Compass
  4. Pressure gauge
  5. Manometer
  6. VOM/test leads/ammeter
  7. Flow meter
  8. Tachometer
  9. pH meter
  10. Hydrometer

B. Collection of data
  1. Location
    a. Environment - solar radiation, ambient
    b. Building load - space heat, hot water
    c. Energy system - collection efficiency and heat removal
  2. Type
    a. Primary data - thermal
    b. Secondary data - mechanical
  3. Uses
    a. Thermal performance
    b. Component efficiency
    c. System modeling
    d. Repair of equipment

Reference 3, Appendix D

C. Calculations
  1. Thermal performance
    a. Heat removal
    b. Removal efficiency
  2. Mechanical efficiency
    a. Power factor
    b. Use of efficiency curve

D. Performance evaluation
  1. Thermal
    a. Predicted efficiency
    b. Actual performance
  2. Mechanical
    a. Operating energy
    b. Reliability of materials

E. Overall system performance
  1. Solar fraction
  2. Electric and fossil energy input

3. Uncontrolled losses

F. Use of charts and reports

G. Improving performance approaches
  1. Improve the accuracy of information on energy use requirements
  2. Choosing correct hardware, auxiliary energy sources and subsystems
  3. Appropriate system design and configuration choices
  4. Careful and attentive installations
  5. Maximizing collection and use through effective operation and maintenance
  6. Monitor system performance periodically to be aware of developing problems and failures

STUDENT ACTIVITY

Exercise

Laboratory:

1. Using appropriate data collection tools; collect, analyze and evaluate the:
   a. Thermal transfer of collector.
   b. Instantaneous efficiency.
   c. Evaluate this against collector efficiency curve.
   d. Determine heat loss occurring in transport.
   e. Energy exchanged into tank.
2. Formulate generalized system operational diagnostic flow diagram.
3. Construct an energy flow diagram and describe its use as an analytical tool.

MODULE: SITE EVALUATION - MACRO TO MICRO

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) List setting variables which affect solar system operations and safety.

(2) Describe aspects of buildings which affect solar system performance.

(3) Determine the type, structural problems, and general condition of solar energy systems.

REFERENCES:

(1) Installation Guidelines for Solar DHW Systems, In One and Two-Family Dwellings, 2nd edition, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(2) HUD Intermediate Property Standards Supplement, 1977 edition, Solar Heating and Domestic Hot Water Systems, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(3) Site Planning for Solar Access, A Guidebook for Residential Developers and Site Planners, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(4) Solar Domestic Hot Water System Inspection and Performance Evaluation Handbook, Draft, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

UNIT TITLES:

(1) Environmental Assessment

(2) Building Assessment

(3) Energy System Inspection

VOCABULARY:

Solar Window

Thermal Expansion

Orientation

Audio

Isogenic Map

Visual

Outgassing

Corrosion

Safety

Leaks

Inspection

Insulation

Micro Climate

Tactile

Unit 1. Environmental Assessment

Reference 3, pg. 13-30

- A. Climatic data
  - 1. Insolation levels
  - 2. Precipitation and humidity
  - 3. Airborne pollutants
  - 4. Ambient temperature
  - 5. Wind
  - 6. Locally specific water quality
- B. Landscaping
  - 1. Topography
  - 2. Vegetation
  - 3. Man-made structures
  - 4. Proximity to bodies of water
- C. Solar access
  - 1. Latitude/longitude
  - 2. Shading patterns
  - 3. Sky window

Unit 2. Building Assessment

- A. Design/orientation
  - 1. East-west axis
  - 2. Wall configuration
  - 3. Internal air flow patterns
  - 4. Light control
  - 5. Roof orientation/configuration
- B. Occupant use
  - 1. Space use
  - 2. Traffic patterns
  - 3. Comfort factors
  - 4. Load management
- C. Thermal loads
  - 1. Structural materials
  - 2. Conservation features
  - 3. Heat control
  - 4. Glazings

Unit 3. Energy System Inspection Overview

- A. Skills - use and development of
  - 1. Visual
  - 2. Listening (sound)
  - 3. Tactile (touch)
  - 4. Improvement of skills as experience develops
- B. Identify type of system
  - 1. Available installation guides
  - 2. Drawings by inspector
- C. Design related problems

Reference 4, pg. xiii

1. Determine if sized properly
    a. Rules of thumb
    b. Detail size methods
    c. Review previous sizing figures
2. System configuration/ layout
    a. Manifolds
    b. Distribution layout
    c. Storage area
    d. Modes of operation

D. Installation related problems

Reference 2, Chapter 5

Reference 4, Section 3

1. Check structural integrity
    a. Tank location
    b. Distribution network
        1) Use of hangers
        2) Straps
        3) Level: plans
    c. Collector mounting techniques

Reference 2, pg. 20

        1) Fastening methods
        2) Wind loading capacity
2. Observe and note system physical condition
    a. Installation quality
        1) Aesthetics
        2) Material compatibility
        3) Workmanship
        4) Safety
            a) Protection of potable water
            b) Electrical shocks
    b. Weatherability
        1) Roof leaks
        2) Components - degradation of materials exposed to environment
            a) Collectors
            b) Insulation
            c) Outside storage

Reference 2, Chapter 5

- d) Electrical wiring
- e) Vents/valves
- 3) Inspection of system components
  - a) Workability - quiet, smooth, efficient operation
  - b) Safety
  - c) Proper drainage disposal
  - d) Glare from collectors
  - e) Prevention of scalding and burning
  - f) Protection from snow and ice falls off collectors
  - g) Electrical connections
  - h) System pressure protection

E. Uses of inspection
  1. Code compliance
  2. Service and maintenance
  3. Economic evaluation
  4. Performance checks

ACTIVITY

Laboratory:

1. Complete Lab No. 5, in Lab Section.
2. Complete Lab No. 6, in Lab Section.
3. Visit a residential construction site reviewing that site for the above stated concerns.
4. Visit a site with an installed system and perform an energy system inspection.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe problems associated with major subsystem components.

(2) Identify possible causes of problem areas.

(3) Demonstrate proper repair/replacement procedures.

REFERENCES:

(1) Interim Reliability and Materials Design Guidelines for Solar DHW System, ANL/SDP-9, available from NTIS, U.S. Department of Commerce, Springfield, Virginia 22161.

(2) Solar Domestic Hot Water System Inspection and Performance Evaluation Handbook, Draft, available from, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161; Doc. No. SERI/SP-98189-1B, October 1981.

(3) Klima, Jon, The Solar Controls Book, 1981, Solar Training Publications, 10921 W. Exposition Drive, Lakewood, Colorado 80226.

(4) Solar Heating and Cooling Systems Operational Results, Conference, Proceedings, Colorado 1978, U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830, Doc. No. Solar/0500-79/00.

(5) Active Solar Energy System Design Practice Manual, October 1979, No. Solar/0802-79/01, U.S. Department of Energy, Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

(6) Solar Heating Materials Handbook, January 1981, NTIS, U.S. Department of Commerce, 5385 Port Royal Road, Springfield, Virginia 22161.

(7) Solar Design and Installation Experience, May 1981, No. Solar/0009-81/37, U.S. Department of Energy, Technical Information Center, P.O. Box Oak Ridge, Tennessee 37830.

UNIT TITLES:

(1) Collectors

(2) Storage

(3) Controls

VOCABULARY:

Flow Distribution
Thermal Expansion
Bellows
Degradation
Outgassing
Hysteresis
Installation Induced
Triacs
Range
Integrated Circuit
Thermocouples
Relays
Thermostats
Differentials
Aquastats
Calibration
Set-Points
Actuators
Thermistor
Accuracy

Reference 1, Section 2.1.1

Unit 1. Collectors

- A. Flow distribution - cause of uneven heating and loss of collectible energy in a collector and array

Reference 7, pg. 38

  - 1. Check for clogged tubing in collector
  - 2. Collector loop valves closed
  - 3. Low head pressure on pump
  - 4. Air traps in collector loop
- B. Thermal expansion - improper leads to buckles and breaks in distribution network

Reference 2, pg. 3.20

  - 1. Cause outsides of manifolds to break lose first (expansion is additive toward outside)
  - 2. Source of rubbing and tearing of roof materials
  - 3. Source of leaks in manifold and transfer lines (air liquid)
  - 4. Use of bellows, pipe expansion designs, etc., can prevent undue damage
- C. Materials - notice signs of degradation to exposed materials

Reference 6, Chap. 4

  - 1. Glazings
    - a. Breakage - thermal, mechanical
    - b. Tears
    - c. Yellowing
    - d. Dirt

Reference 6, Chap. 6

  - 2. Seals/sealing compounds
    - a. Throughout system
    - b. Material response
    - c. Materials response properties

Reference 6, Chap. 8

  - 3. Absorber plates
    - a. Bent on warped plates
    - b. Excessive moisture inside boxes (frames)
    - c. Chipped or pealing coatings
    - d. Observe signs of plate corrosion

- e. Check for leak tightness
- f. Condition of collector insulation

Reference 6, Chap. 5

- 4. Insulation
  - a. In collector (outgassed; laying loose)
  - b. Around pipe/duct
  - c. On storage containers

Reference 1, pg. 24

- 5. Collector frame
  - a. Corrosion
  - b. Separation from glass due to thermal expansion of insulation
  - c. Clogged weep-hole (build up of water)
  - d. Missing manifold grommets
  - e. Frame warpage

NOTE: In discussion of problem areas, methods of repair and/or replacement should also be addressed

Reference 1, pp. 25-26

- D. Collector failure modes
  - 1. Freezing
    - a. Improper antifreeze mix
    - b. Failure of drain device
    - c. Due to night sky cooling
  - 2. Leaking seals
    - a. Cracked/degraded material
    - b. Glass dislocation from frame
    - c. Improper construction
  - 3. Absorber plate degradation
    - a. Poor application by manufacturer
    - b. Poor coating material selection
    - c. General weatherability

4. Outgassing
    a. Stagnate collector temperatures
    b. Low grade material

Reference 1, Section 2.4
Reference 5, pp. 99-129
pp. 207-221

Unit 2. Storage

A. Mechanical problems
    1. Weight of containers
        a. Foundation supports (beams)
        b. Container construction integrity (rock boxes, concrete, liquid storage)
    2. Location of tank
        a. Inside or outside/ weatherability
        b. Above or below ground - ground proofing
    3. Leak tightness
        a. Liquid - joints and seals
        b. Air - cracks in box and duct
    4. Pipe connections
        a. Locations - above or below water line
        b. Type - soldered, mechanical
        c. Number - few as possible
    5. Materials
        a. Observe material compatibility
        b. Use only those approved by local codes and standards

Reference 6, Chap. 7

    6. Access
        a. To fittings and components
        b. To inside of large tanks
    7. Corrosion
        a. Due to air/liquid mixture
        b. Galvanic action
        c. Improper fluids

Reference 6, Chap. 7

B. Thermal problems
  1. Thermal cycling
    a. Weakening of materials
    b. Insure adequate expansion allowance
  2. Energy loss
    a. Due to excessive temperature (recommend 180°F)
    b. Poor insulation
    c. Evaporative losses in open vented tanks
    d. From saddle supports and legs
  3. Safety equipment
    a. Insure rated pressure and temperature valves function properly
    b. Test high temperature sensors on controllers
    c. Insure heat dumps to proper location (per code requirements)

C. Design problems
  1. Stratification - if required by task, insure per installation
  2. Short circuiting of storage
    a. Liquid - collector inlet/outlet in proximity
    b. Air - avoid use of horizontal boxes unless packing of stones allowed for
  3. Liquid flow velocity - destroys stratification
  4. One - two tank use, that results in poor treatment of application

Reference 7, pp. 44-49

Reference 1, Sections 2, 3, and 4

Unit 3. Controls

A. Design failures
  1. Logic - sequences
    a. Hysteresis
    b. Priorities of activities to occur
  2. Freeze protection
    a. Collector

        b. Storage
- B. Sensor location and installation failures
    - 1. For differential control
    - 2. For freeze protection
    - 3. For auxiliary
        - a. DHW
        - b. Space heating
    - 4. Installation induced hysteresis
- C. Set points and calibration
    - 1. Selection of set points - low-side ΔT
        - a. For task (DHW, space heat)
        - b. Determining set points
    - 2. Calibration
        - a. How frequent
        - b. Procedure for each sensor
        - c. Test instruments
- D. Control component failures
    - 1. Classes of failures
        - a. Mechanical
        - b. Electrical
    - 2. Sensors
    - 3. Controllers
        - a. Transformers
        - b. Triacs
        - c. Relays
            - 1. Contacts
            - 2. Coils
        - d. Capacitors
        - e. Resistors
        - f. Operational amplifiers
    - 4. Actuators
        - a. Pumps
        - b. Fans
        - c. Solenoids
- E. Sensors
    - 1. Thermistor - (NTC, 2 wire, non-linear)
        - a. Range - 200°C to 350°C
        - b. Accuracy
        - c. Signal change - 4 - 6 percent/°C

2. Integrated circuit (PTC, 2 + wires, linear)
    a. Range - -30°C to 180°C
    b. Accuracy - ± .5°C
    c. Signal Change - 1 percent/°C
3. Thermocouple (PTC, 2 wire, linear)
    a. Range - 180° to 1500°C
    b. Accuracy - ± 1°C
    c. Signal change - .2 percent/°C
4. Platinum alloy (PTC, 2 wire, linear)
    a. Range - -180° C to 1100°C
    b. Accuracy - ± .3°C
    c. Signal change - .5 percent/°C

STUDENT ACTIVITY

Laboratory:

1. Construct a troubleshooting chart for each of the major system components to contain the following:
    a. Symptom
    b. Probable Cause
    c. Remedies
        1. Repair
        2. Replace
2. Use available laboratory equipment simulate the actual repair or replacement of defective equipment.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe problems associated with support devices and probable causes for failure.

(2) Demonstrate skills in repair and/or replacement of components.

(3) Describe effects of components malfunction on system performance.

REFERENCES:

(1) Emerick, Robert H., Trouble-Shooter's Handbook for Mechanical Systems, McGraw-Hill, 1969.

(2) Installation Guidelines for Solar DHW Systems, In One Or Two-Family Dwellings, Second Edition, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(3) Solar Heating Materials Handbook, January 1981, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

(4) Interim Reliability and Materials Design Guidelines for Solar Domestic Hot Water Systems, ANL/SDP-9, Available NTIS, U.S. Department of Commerce, Springfield, Virginia 22161.

(5) Solar Domestic Hot Water System Inspection and Performance Evaluation Handbook, Draft, available from, NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161; Doc. No. SERI/SP-98189-1B, October 1981.

(6) Solar Heating Materials Handbook, January 1981, NTIS, U.S. Department of Commerce, 5385 Port Royal Road, Springfield, Virginia 22161.

UNIT TITLES:

(1) Pumps/Blowers

(2) Valves/Dampers

(3) Pipes/Ducts

(4) Electrical Devices

(5) Miscellaneous

VOCABULARY:

Prime
Deterioration
Solenoid
Specific Gravity
Reliability
Viscosity
Dynamic Head
U.V. Resistance
Water Hammer

Reference 4, pp. 80-85

Unit 1. Pumps/Blowers

- A. Pumps - problems/causes
  - 1. Reduced delivery
    - a. Air leak in suction side piping

Reference 5, Section 3.3

    - b. Check for proper speed (low voltage)
    - c. Check bearings for wear
    - d. Clogged impeller
  - 2. Excessive vibration
    - a. Pump rotor shaft may be bent
    - b. Check mechanical alignment
    - c. Foundation bolts loose
  - 3. Pump operation is noisy
    - a. Cavitation in impeller
    - b. Reduced volume of fluid being moved
    - c. Excessive fluid velocity (recommend 4 to 5 ft./sec.)
  - 4. Loss of prime
    - a. Air leak on suction side of pump
    - b. Excessive air in water
  - 5. Pump uses excessive amount of power
    - a. Speed too high
    - b. Total dynamic head lower than pump rating
    - c. Pipe may be excessively corrosive
    - d. Specific gravity and viscosity different from pump rating
- B. Blowers - problems/causes
  - 1. Reduced delivery

Reference 1, Chap. 4

    - a. Too small fan
    - b. Excessive head pressure
    - c. Clogged filter

2. Excessive vibration
    - a. Loose mounting to motor shaft
    - b. Loose mechanical connections to casing
3. Excessive noise
    - a. Fan too large
    - b. Belt drive loose
4. Excessive power requirements
    - a. Poor electrical connections
    - b. Dirty house filter

Unit 2. Valves/Dampers

A. Valves - problems/solutions

Reference 4, pp. 85-89

1. Leaks
    - a. Poor seating
    - b. Valve packing
2. Failure to open or close
    - a. Dirty/broken stem
    - b. Solenoid - failure of drive mechanism
3. Reliability of valves
    - a. Manual valves - 5-20 years
    - b. Check valves - 10 years, 100 years
    - c. Spring loaded pressure relief - 10-20 years
    - d. Solenoid valves - at least 2 years, high quality approximately 20 years
4. Types of valves
    - a. Hand-operated
        1. Globe
        2. Gate
        3. Ball
    - b. Power actuator
        1. Solenoids
        2. Diverter
    - c. Other valves
        1. Check valves
        2. PRV's
        3. Vacuum relief
        4. Air vent
        5. Tempering

Reference 4, pp. 90-92

B. Dampers
  1. Types of dampers
    a. Manual
    b. Powered
    c. Back draft
  2. Manual dampers
    a. Insure positive close and open
    b. Smooth mechanical action
  3. Powered dampers
    a. Insure positive close and open
    b. Check for proper supply voltage
    c. Check for effective weather stripping
  4. Back draft damper
    a. Proper location - not in backwards
    b. Insure positive close - no creases or folds
    c. No holes, in materials

Reference 5, Section 3.2

Unit 3. Piping/Ducts
A. Piping - problems/causes
  1. Water hammer
    a. Too small size pipe
    b. Poor or no hammer arresters
  2. Leaks
    a. Poor connections (soldered/mechanical)
    b. Due to water hammer
    c. Pipe freezes
  3. Noisy lines
    a. Fluid velocity too high
    b. Air in lines
  4. Corrosion
    a. Mixed metals
    b. Poor fluid quality
    c. Failure to clean joints properly
  5. Reduced flow capacity per design
    a. Pipe too small
    b. Liquid viscosity higher than expected

- c. Pipe interior seriously fouled by deposits

- B. Ducts - problems/causes
  - 1. Leaks
    - a. Opening in lines due to deterioration or tears
    - b. Poor connections
    - c. Excessive air pressure
  - 2. Noisy ducts
    - a. Too small duct diameter
    - b. Transmitted sound from other sources (i.e. fan noise)
  - 3. Too low desired volume
    - a. Leaks
    - b. Too small diameter duct

Reference 1, Chap. 5

Unit 4. Electrical Devices

- A. Types of devices
  - 1. Motors
  - 2. Controllers
  - 3. Relays/contractors
  - 4. Transformers
  - 5. Solenoids
  - 6. Meters (flow, Btu)
- B. Problems associated with electrical devices
  - 1. Low voltages
  - 2. Burnt coils
  - 3. Improper wiring
  - 4. Loose connections
  - 5. Weatherability
  - 6. Incorrect set points on controllers
  - 7. Incorrectly sized transformers
  - 8. Sticky solenoid valves
  - 9. Incorrect wire sizes
  - 10. Shorts or open circuits
  - 11. Too tight motor bearings
  - 12. Burnt contacts
  - 13. Motor overloads

Reference 5, Section 3.7

Unit 5. Miscellaneous

- A. Transfer fluids
  - 1. Improper fluid used for task
  - 2. Too high/low viscosity
  - 3. Scaling
  - 4. Corrosion

5. Toxicity
6. Improper freeze protection mixture

Reference 6, pp. 51-97
pp. 191-195

B. Collector mounting
   1. Poor selection of materials
   2. Poor construction techniques
   3. Improper roof penetrations

C. Gauges
   1. Broken glass
   2. Sticking needles
   3. Clogged gauge openings
   4. Out of calibration

Reference 6, pg. 131-144

D. Protective devices
   1. Worn springs on pressure/temperature relief valves
   2. Improper design valve selection
   3. Improper location for effective protection

Reference 3, Chap. 6

E. Seals/sealants
   1. Poor weatherability
   2. Poor thermal characteristics
   3. Poor application of (leaks)
   4. No U.V. resistant

STUDENT ACTIVITY

Laboratory:

1. From previously identified subsystem components, develop a troubleshooting guide describing:
   a. Symptoms
   b. Probable cause
   c. Repair or replacement procedures.
2. Complete Lab No. 8.
3. Using appropriate litmus paper, perform a liquid quality check on any available liquid system.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe normal operating procedures for SDHW systems types.

(2) Identify possible failure modes which affect system reliability.

(3) Prescribe solutions to subsystem and component failures.

REFERENCES:

(1) Interim Reliability and Materials Design Guidelines for Solar DHW Systems, ANL/SDP-9, available from NTIS, U.S. Department of Commerce, Springfield, Virginia 22161.

(2) Solar Domestic Hot Water System Inspection and Performance Evaluation Handbook, Draft, available from, National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161, Doc. No. SERI/SP-98189-1B, October 1981.

(3) Installation and Operations Manual from Manufacturers, i.e., Lennox, Grumman, Bio-Energy, Sunworks, Solar Development Inc.

(4) Comparative Report: Performance of Active SDHW Systems, No. Solar/0024-80/41, available from National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22161.

UNIT TITLES:

(1) Passive-Thermosyphon

(2) Passive-Batch

(3) Drainback

(4) Draindown

(5) Recirculation

(6) Closed-Loop (Antifreeze)

(7) Air System-Water Coil

(8) Refrigerant Charged

VOCABULARY:

Thermosyphon
Recirculation
Auxiliary Heat
Vacuum Breaker
Exchanger
Drain
Normally Closed
Direct Headed
Troubleshooting
Draindown
Solenoid
Closed-Loop
Control Schematic
Normally Open
Performance
Controller
Drainback
Indirect Heated

Reference 2, Sections 2.2 and 2.6

Unit 1. Passive - Thermosyphon
- A. Description of system
    - 1. System configuration
    - 2. Component requirements

Reference 1, pg. 145

- B. Normal operational characteristics
    - 1. General performance characteristics
    - 2. Energy requirements
- C. Failure analysis
    - 1. Subsystem problems
    - 2. Component failure
    - 3. Design errors
- D. Solutions
    - 1. Repair - component
    - 2. Replace - component
    - 3. Redesign - system

Unit 2. Passive - Batch
- A. Description of system
    - 1. System configuration
    - 2. Component requirement
- B. Normal operational characteristics
    - 1. General performance characteristics
    - 2. Energy requirements
- C. Failure analysis
    - 1. System problems
    - 2. Component failures
    - 3. Design errors
- D. Solutions
    - 1. Repair - component
    - 2. Replace - component
    - 3. Redesign - system

Reference 2, Section 2.1

Reference 1, pg. 160

Unit 3. Drainback
- A. Description of system
    - 1. System configuration
    - 2. Component requirement
- B. Normal operational characteristics
    - 1. General performance characteristics
    - 2. Energy requirements
- C. Failure analysis
    - 1. System problems
    - 2. Component failures
    - 3. Design errors
- D. Solutions
    - 1. Repair - component
    - 2. Replace - component
    - 3. Redesign - system

Reference 1, pg. 119

Reference 2, Section 2.1

Unit 4. Draindown
- A. Description of system
  - 1. System configuration
  - 2. Component requirement
- B. Normal operational characteristics
  - 1. General performance characteristics
  - 2. Energy requirements
- C. Failure analysis
  - 1. System problems
  - 2. Component failures
  - 3. Design errors
- D. Solutions
  - 1. Repair - component
  - 2. Replace - component
  - 3. Redesign - system

Reference 1, pg. 135

Reference 2, Section 2.1

Unit 5. Recirculation
- A. Description of system
  - 1. System configuration
  - 2. Component requirement
- B. Normal operational characteristics
  - 1. General performance characteristics
  - 2. Energy requirements
- C. Failure analysis
  - 1. System problems
  - 2. Component failures
  - 3. Design errors
- D. Solutions
  - 1. Repair - component
  - 2. Replace - component
  - 3. Redesign - system

Reference 1, pg. 177
Reference 2, Section 3 & 4

Unit 6. Closed-Loop (Antifreeze)
- A. Description of system
  - 1. System configuration
  - 2. Component requirement
- B. Normal operation
  - 1. General performance characteristics
  - 2. Energy requirements
- C. Failure analysis
  - 1. System problems
  - 2. Component failures
  - 3. Design errors
- D. Solutions
  - 1. Repair - component
  - 2. Replace - component
  - 3. Redesign - system

Reference 2, Section 2.5
Reference 1, pg. 1931

Unit 7. Air System - Water Coil

- A. Description of system
  - 1. System configuration
  - 2. Component requirements
- B. Normal operational characteristics
  - 1. General performance characteristics
  - 2. Energy requirements
- C. Failure analysis
  - 1. Subsystem problems
  - 2. Component failure
  - 3. Design errors
- D. Solutions
  - 1. Repair - component
  - 2. Replace - component
  - 3. Redesign - system

Reference 1, Appendix E

Unit 8. Refrigerant Charged

- A. Description of system
  - 1. System configuration
  - 2. Component requirements
- B. Normal operational characteristics
  - 1. General performance characteristics
  - 2. Energy requirements
- C. Failure analysis
  - 1. Subsystem problems
  - 2. Component failure
  - 3. Design errors
- D. Solutions
  - 1. Repair - component
  - 2. Replace - component
  - 3. Redesign - system

STUDENT ACTIVITY

Laboratory:

1. Complete Lab No. 2.
2. Complete Lab No. 3.
3. Perform an evaluation as to the most effective and reliable system in terms of cost and Btu's delivered for a given geographic location.

MODULE: SWIMMING POOLS, SPAS AND HOT TUBS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe two styles of pool flow control designs.

(2) Identify possible failure modes which affect system reliability and describe appropriate repairs.

(3) Describe the typical start-up procedures.

(4) Develop a troubleshooting flow chart for a system.

REFERENCES:

(1) *Solar Heating for Swimming Pools*, Florida Conservation Foundation, Inc., 935 Orange Ave., Winter Park, Florida 32789, 1980.

(2) *Solar Water and Pool Heating Installation and Operation*, Florida Solar Energy Center, Cape Canaveral, Florida, 1979.

(3) Installation and Operations Manuals of Fafco, Bio-Energy, and Solar Industries Inc.

UNIT TITLES:

(1) Pools

(2) Spas

(3) Hot Tubs

VOCABULARY:

Glazed/Unglazed Collectors
Booster Pump
Pilot Operating Valve
Pool Support Devices
Diverting Valve
Backwashing
Pete's Plug
Seasonal Heating

Unit 1. Swimming Pools
A. Physical description

Reference 3 (the use of manufacturer's use manuals provide more thorough examples than do most other texts)
Reference 2, pp. 5-14
Reference 2, pp. 5-21

1. Collectors
  a. Unglazed
  b. Glazed
  c. Metal Panels
  d. Plastic Panels
  e. Pipe
  f. Concentrator/reflectors
2. Control configurations and types
  a. Manual valving
  b. Automatic valving
    1. Single valve
    2. Multiple valve
  c. Booster pump arrangement
  d. Activation devices
  e. Sensor locations
3. Piping and components
  a. Configurations

Reference 2, pp. 5-39
pp. 5-39

  b. Types of pipe
  c. Valves commonly used
    1. Check
    2. Gate
    3. Ball
    4. Boiler drain
  d. Thermometers and Pete's plugs
  e. Vacuum breakers
4. Pool support equipment interface
  a. Location of pool collectors
    1. Proximity to collectors
    2. Above or below pool water level
  b. Filler location
  c. Auxiliary heater (if used)

Reference 2, pg. 5.1

B. Pool operational characteristics
1. Low-temperature application (<90°F) with operation at or near ambient
2. High volume flow rate/total volume turn over
3. Typically low pressure drop system
4. Seasonal heating
5. Year round heating

6. Daytime operation - heating
    a. Sunshine
    b. Intermittent sun
    c. Cloudy
7. Nighttime operation - cooling
8. System start-up procedures
    a. Check all wiring/ plumbing
    b. Isolate collector array - flush collectors
    c. Presume test the collector
    d. Test all modes of the automatic type controller
    e. Adjust flow rates
    f. Insure appropriate pressure range at filter

C. Failure analysis
    1. Lack of adequate heating
    2. Pool too hot
    3. System runs continuously
    4. System does not start
    5. Controller operating backwards
    6. System cycles on and off
    7. Controller fails to operate in automatic
    8. Control malfunctions; no flow to collector
    9. Solenoid valve stuck in place
    10. No collector lights on
    11. Short circuited controller
    12. Leaks at collector and hose couplings
    13. Leaking vacuum breaker
    14. Air being blown into pool continuously
    15. Loss of pump prime
    16. Drainage problems
    17. Freeze damage
    18. System backwashing through filter
    19. Improper pressure reading at filter

20. Corrosion problems - describe types of corrosion
21. Copper/PVC joints

NOTE: Controller problems should be evaluated against the manufacturer's guidelines as most controllers are designed and built differently from each other.

D. Reliability/maintainability
    1. Collector degradation
    2. Valve malfunctions
    3. Differential collectors
    4. Piping
    5. Pumps
    6. Operator error
    7. Design/installation errors

E. Maintenance
    1. Winterizing - consult manufacturer's guidelines
    2. Annual service
    3. Use of manufacturer's installation, operations and maintenance guidelines

STUDENT ACTIVITY

Assignment:

Exercise I

Given knowledge of system design, component requirements, and types of failures, construct a troubleshooting chart for a pool heat system.

Exercise II

Draw a reliability flow chart describing components, moving from the least reliable to the most reliable aspect of pool heat components.

Unit 2. Spas

A. Physical description
    1. Attached/unattached to pools
    2. Typically used glazed panels
    3. Configurations and components
        a. Direct heated
        b. Indirect heated
        c. Auxiliary heating
        d. Spa support packages/components

- B. Spa operational characteristics
    - 1. Low-temperature application (80^{o} - 100^{o}F range)
    - 2. Low volume bypassed to collector area
    - 3. Higher heat requirement in winter
    - 4. Cooler water required in summer
    - 5. Year-round collection
- C. Failure analysis
    - 1. Closed-loop - see systems - DHW
    - 2. Open-loop - see systems - DHW
    - 3. Are temperature ranges maintained
    - 4. Higher temperatures may cause scaling in collectors
    - 5. See pool failure analysis
- D. Reliability and maintainability
- E. Maintenance

Unit 3. Hot Tubs

- A. Physical description
- B. Hot tubs operational characteristics
    - 1. Uses
    - 2. Temperature ranges
- C. Failure analysis
    - 1. Hot tub components
    - 2. Plumbing components
    - 3. Collector loop components
    - 4. Heat exchangers
- D. Reliability and maintainability
- E. Maintenance

STUDENT ACTIVITY

Assignment:

1. Prepare a troubleshooting chart describing possible component failures and their solutions.
2. Visit a local pool/spa dealer and inquire as to reliability of components that they use. Discuss this with class.
3. Analyze various manufacturers' owners manuals and compare system styles.

MODULE: SOLAR AND HVAC

NOTE: Solar and HVAC span a wide range of designs, equipment, and operating ranges. These can include high and low performance collectors, various storage mediums and arrangements, numerous terminal devices, and a variety of heating and cooling equipment. The technician needs to be aware of the range of operating requirements of various hardware. It is the task of the technician/mechanic to determine system failures or reduced performance of the solar-HVAC system independent of each other or as they interface.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe operational problems associated with various residential heating and cooling equipment.

(2) Identify system failures due to interface of solar energy equipment.

(3) Demonstrate repair skills.

REFERENCES:

(1) Solaron Application Engineering Manual - Air Systems, 30 Galleria Tower, 720 South Colorado Blvd., Denver, Colorado 80222.

(2) Solar - Job Related Training (Phase I), Lennox Industries Inc., Education Department, P.O. Box 400450, Dallas, Texas 75240.

(3) Solar Heating and Cooling of Buildings,: Sizing, Installing, and Operations of Systems, 2nd Edition; 1980, Solar Energy Applications Laboratory, Colorado State University.

(4) Refrigeration and Air Conditioning; ARI, 1979, Prentice-Hall Publishing, ARI, 1815 North Fort Meyer Dr., Arlington, Virginia, 22209.

(5) Langley, Billy, Comfort Heating, 2nd Edition, 1978, Reston Publishing Co., Inc., Reston, Virginia, 22090.

(6) Langley, Billy, Refrigeration and Air Conditioning, 1978, Reston Publishing Co., Inc., Reston, Virginia 22090.

(7) ASHRAE Handbook of Experiences in the Design, Installation and Operation of Solar Heating and Cooling Systems.

UNIT TITLES:

(1) Space Heating

(2) Space Cooling

(3) Photovoltaic Augmented Systems

VOCABULARY:

Gas Furnace
Electric Furnace
Low Voltage Circuit
Heat Anticipator
Pilot
Limit Control
Air to Air Heatpump
Operational Problems
Collector-Load Relationship
Water To Air Heatpump
Photovoltaic Augmenter
Thermostat
Sequencer
Reversing Value
Aquastat
Defrost Heater
Compressor
Resistance Heating
Baseboard Heating
Duct Heaters
Solar Assist
Thermostat
Cooling Tower
Lithium-Bromide
Hydronic
Air Velocity
Time Delay Relay
DC Circuits
DC/AC Inverters
DC Components

Unit 1. Space Heating

Reference 5, pg. 297

- A. Gas furnace - solar heat system
  - 1. Thermostat operation problems
    - a. Low voltage circuit
    - b. Heat anticipator
    - c. Gas valve connection
    - d. Transformer

Reference 5, pg. 218

  - 2. Gas system operational problems
    - a. Fan control
    - b. Limit control
    - c. Gas valve
    - d. Pilot
    - e. Air flow circuit (exchanger)
    - f. Poor combustion
    - g. Venting

Reference 1 (troubleshooting)
Reference 2 (operation)

  - 3. Solar system operational
    - a. Air systems
    - b. Liquid systems
    - c. Collector-load relationship (seasonal operational problems)
  - 4. Interface problems

Reference 2 (controls)

    - a. Thermostat staging
    - b. Solar hydronic coil location
    - c. Effects of reduced air velocities
    - d. Storage to load circuit component failures
- B. Electric furnace - space heating system

Reference 5, pg. 304

  - 1. Thermostat operational problems
    - a. Similar to gas system thermostat
    - b. Time delay relay
    - c. Limit controls
    - d. Over current protector
    - e. Sequencer
  - 2. Electric furnace operational problems

Reference 5, pg. 130

    - a. Resistance heating
    - b. Baseboard heating
    - c. Duct heaters

3. Solar heat system operational problems
    - a. Air systems
    - b. Liquid systems
    - c. Collector-load relationship
4. Interface problems
    - a. Thermostat staging
    - b. Solar hydronic coil location

      Reference 5, pg. 137
    - c. Effects of reduced
    - d. Storage to load circuit component failures

C. Heat pump

1. Air-to-air heat pump - solar assist

   Reference 6, pp. 644-648
    - a. Control staging
        - 1. Thermostat
        - 2. Aquastat
    - b. Heat pump operational problems
        - 1. Mechanical
            - a. Reversing
            - b. Defrost heater
            - c. Compressor
            - d. Indoor/outdoor coils
        - 2. Ambient limitations
    - c. Solar heat system operational problems
        - 1. Aquastat (low limit)
        - 2. Flow control
        - 3. Air systems
        - 4. Liquid systems
    - d. Interface problems
        - 1. Control logic
        - 2. Hydronic coil location
        - 3. Air velocities
        - 4. Storage to load circuit component failures
2. Water-to-air heat pump - solar assist
    - a. Control staging
        - 1. Thermostat
        - 2. Aquastat

- b. Heatpump operational problems
  - 1. Low-temp cut-off (40°F)
  - 2. Flowpump
  - 3. Water solenoid valve shut off
- c. Solar heat system operational problems
  - 1. Collection circuit
  - 2. Differential and aquastat
- d. Interface problems
  - 1. Maintenance of adequate storage temperature
  - 2. Exchange flow rate
  - 3. Cooling tower operation during summer

Unit 2. Space cooling

Reference 3, pp. 5-8

- A. Absorption cooling
  - 1. Collection circuit operational problems
    - a. Collection loop (typically open-loop)
    - b. Storage type (non-pressurized)
    - c. Differential controls
    - d. Collection fluid maintenance
      - 1. Quality
      - 2. Level of water

Reference 4

  - 2. Absorption cooling equipment
    - a. Generator
    - b. Condenser
    - c. Evaporator
    - d. Absorber
  - 3. Terminal equipment
    - a. Solenoid switching-seasonal
      - 1. Space heating loop
      - 2. Space cooling loop

- b. Terminal hydronic exchanger
    - 1. Flow rates
    - 2. Pressure requirements

Reference 4, pg. 232

- c. Cooling tower
    - 1. Pumps/fans
    - 2. Scaling
    - 3. Corrosion

NOTE: Absorption cooling systems can be complex and technically difficult. Consult manufacturer's specifications for exacting information about system operation.

Unit 3. Photovoltaic Augmented Systems

- A. Water pumping - DHW
    - 1. DC motor problems
    - 2. Circuit continuity
    - 3. Electrical connections
    - 4. Power matching
- B. Ventilating system
    - 1. DC fan motor problems
    - 2. Circuit continuity
    - 3. Electrical connections
    - 4. Power matching
- C. Photovoltaic powered heat-pumps
    - 1. Electrical circuits
    - 2. Power matching
    - 3. DC/AC inverters
    - 4. Connection to electrical grid

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the job related activities of service technicians and how they relate to the well-being of solar energy systems' optimum operations.

(2) Determine the reliability and maintainability of components used in solar systems.

(3) Develop periodic maintenance schedules for liquid and air heat systems.

REFERENCES:

(1) Fundamentals of Solar Heating, Sheet Metal and Air Conditioning Contractors National Association, 8224 Old Court House Road, Vienna, Virginia, January 1978.

(2) Installation Guidelines for Solar DHW Systems; In One And Two-Family Dwellings, Second Edition, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

(3) Interim Reliability and Materials Design Guidelines for Solar Domestic Hot Water Systems, Argonne National Laboratory, National Technical Information Services, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22162.

(4) Solar Domestic Hot Water System Inspection and Evaluation Handbook, Solar Environmental Engineering Company, Inc., National Technical Information Services, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161.

UNIT TITLES:

(1) Service

(2) Maintenance

(3) Reliability and Maintainability

(4) Miscellaneous

VOCABULARY:

Periodic Maintenance

Operational Checklist

Installation Checklist

Failure Rate Curve

Start-Up

Reliability

Work Space

Troubleshooting

Reference 1, Chapter 10

Unit 1. Service
- A. Start-up responsibility
  - 1. Liquid
  - 2. Air
  - 3. Operational checklists
- B. Maintenance responsibilities
  - 1. Technician
  - 2. Homeowner

Reference 4, pg. A.17
Reference 2, pg. 79

Unit 2. Maintenance (may vary by system)
- A. Periodic
  - 1. Wash glazing and inspect collector array for degradation
  - 2. Check antifreeze fluid; maintain as necessary
  - 3. Perform typical system inspection; repair as required
- B. Schedules/records
  - 1. Construct schedules to reflect installed system and dates due for periodic maintenance
  - 2. Make records of each system
    - a. Design information
    - b. Drawings
    - c. Person who installed system
    - d. Particulars of site
    - e. Other information as required to completely inform about system and its operation
  - 3. Warranty obligations

Unit 3. Reliability and Maintenance
- A. Objective of reliability analysis
  - 1. Assess reliability of existing systems or proposed design configurations
  - 2. Minimize mortality failures by development and testing
  - 3. Develop recommendations for improving system reliability and achieving low frequency of failures

4. Insure that reliability is as important as performance and cost

Reference 3, Appendix A

B. Assessing reliability
   1. Failure rate curve
      a. Break-in period (high failure rate)
         1) Design errors
         2) Design omissions
         3) Operator error
      b. Useful life (failures are random)
         1) Fatigue
         2) Creep
         3) Poor maintenance
      c. Wearout (failure rate increases)
         1) Overhaul
         2) Abandon
      d. Component reliability
         1) Failure rate (a function of operating conditions, materials of construction and quality of construction)
         2) Amount of time component is subjected to operating conditions
   2. System reliability
      a. Good system performance depends heavily on the combined operation of that system
      b. Parallel combinations
         1) Component failure will not disable system
         2) Could result in drastically lowered system efficiency

        3) Malfunction can be masked by parallel component (i.e., pumps controlled by flow sensing devices)
    c. Series combinations
        1) Component failure will disable system
        2) System reliability is only as good as the least reliable component

Unit 4. Miscellaneous
- A. Express safety consciousness
    - 1. Garages
    - 2. Storerooms
    - 3. Attics
    - 4. Roofs
    - 5. Inside house living spaces
    - 6. Keep work area clean
- B. Installation aesthetics
- C. Final clean-up
- D. Informing the homeowner

STUDENT ACTIVITY

Assignment:

1. Construct a service and maintenance sheet on a residence containing a SDHW system.

   Include:

   Location,

   Date of installation or inspection,

   Type of system,

   Major components brand name,

   Problems,

   Time at site,

   Work performed,

   Signature block,

   Etc.

2. Write a paper describing the various residential work locations, typical tools in use, potential dangers, and the need to maintain safety consciousness.

OPERATIONAL DIAGNOSIS

Representative Labs

LAB: OPERATIONAL DIAGNOSIS

Lab 1: Liquid System Controls - Closed-Loop

VIII-63

1. Prepare a schematic diagram of a typical liquid solar hot water/ space heat system locating all components and controls for the system.

2. From your prior study experience, prepare a table showing the control action/positions when the system is to operate in each of the following modes:

   a. Space heating from collectors only.

   b. Space heating from storage only.

   c. Space heating from collectors and storage

   d. Storage heating from collectors only.

   e. Hot water heating from collectors/storage.

3. Based on your course work to date, identify potential system malfunctions and the corrective action you would recommend.

Lab 2: Liquid System Controls - Draindown

1. Liquid solar systems can be designed to provide automatic freeze protection without the use of an anti-freeze heat transfer liquid. Such systems are either "drain-down" or "drain-back".

   Prepare a schematic diagram of a "drain-down" liquid system.

   a) Identify all system components.

   b) Provide a brief, but detailed, discussion of the operating modes for normal and freeze shutdown conditions.

2. After completion of a) above, check out the instruction manual for the RT-5 solar cycle trainer and become familiar with this equipment.

Return instruction manual before departing lab area.

Lab 3: Liquid System Controls - Drainback

Direct pumped solar systems such as drain down and drain back systems require no antifreeze solution since the system design provides freeze protection.

1. Provide a schematic diagram of a drain back solar system and:
    a. Identify all components of the system.
    b. Provide a brief, but detailed, discussion of the operating sequences for:
        1) Normal operating mode
        2) Freeze protection mode
2. After completion of above lab, check out the instructors manual for ST-17 trainers and become familiar with this piece of equipment (capabilities).

Return manual to lab assistant before leaving the laboratory.

Lab 4: Air System Controls

Solar air systems operate using dampers to direct air flow in the different operating modes. This requirement usually demands several dampers (including back-draft dampers) to provide air distribution to components and space in a solar space heating/DHW system.

1. Inspect the air system for the demo house and
   a. Draw a schematic diagram of the system
   b. Label the components and identify the dampers by number

2. Describe briefly, but in detail, the operating sequence in each mode for the air system above.

NOTE: Damper positions - open or closed - should be included in the operational description. Use damper numbers so that it will be clear as to which damper is referenced.

Lab 5: Performance Factors - Siting and Tilt Angles VIII-71

Two factors that directly affect optimum performance of a thermal solar system are array orientation and tilt angle. Many customer complaints originate from improper installations; therefore, the technician must be able to determine the expected performance of the system. Orientation and tilt angle is directly related to system performance.

1. Using the Solar Site Selector (or a quality compass), determine the orientation of: (See back sheets for instructions)
   a. The liquid system array on the roof of the Solar Lab.
   b. The liquid and air system array on the roof of the demo house.

2. Determine the array tilt angle of the two systems in No. 1 above.

Lab 6: Performance Factors - Shading

System performance can be adversely affected by the shade cast by trees, buildings, earth mounds and other obstructions, including one solar array shading another.

1. Using the Solar Site Selector, (see back sheets for instructions), determine the shading percentage of the liquid system and air system arrays on the roof at

    9:00 A.M. __________

    10:00 A.M. __________

    2:00 P.M. __________

    3:00 P.M. __________

2. (Alternative method). Using appropriate math and equations shown in attached sheet from Solaron manual, complete requirements for No. 1 above.

Lab 7: Performance Factors - Array and Auxiliary Sizing VIII-75

Often the problem, that results in a customer complaint, is simply that the solar system is not properly sized or the delivery system is inadequate or unbalanced. Also the auxiliary (back-up) system is an integral part of the total system; therefore, it must be analyzed as a potential contributor to the fault.

1. Given a sketch of a floor plan and zone loads (summer and winter) including DHW, analyze system - solar and auxiliary - capability to meet energy demands.
2. Make recommendations as to how load and use patterns could be changed, resulting in optimum system performance in meeting energy requirements.

Lab 8: Installation Problems

Evaluation of system installations is a necessary skill for the successful technician. Component reliability, failure rate and serviceability provides insight to intuitive diagnosis of problems. Each installation is different in some way. When making the inspection, use a critical eye as well as listening and feeling. You are looking for potential problems. THINK SYSTEM and do not forget the back-up system.

1. Evaluate the liquid system in the solar lab by
    a. Locate and identify components that are likely to cause problems or system failure.
    b. Make recommendations for changes that would result in better performance and/or serviceability.

2. Repeat No. 1 for air system in Solar Lab.

Lab 9: Differential Temperature Controls - Temperature VIII-79

The "heart" of the solar control system is the controller which is usually a differential temperature controller. It tells the operational devices when they are to be energized (or de-energized) and in what sequence.

Basically the DTC is a comparator circuit, comparing values established by temperature difference in various sensing devices. These sensing devices may be thermistors - with a positive or negative temperature coefficients - or thermal switches - normally open or normally closed. There are many other methods of "sending signals" to the master controller, but these are the most common.

The purpose of this lab is to develop skills in determining the type and characteristics of the sensors used in various controllers.

1. Obtain 2 each of three different valve thermistors and 2 plastic bags to fit over the thermistor body.

2. Using a piece of graph paper, lay out a x and y axis graph. y axis (at bottom of paper) will represent resistance in ohms and the x axis (left margin) will represent temperature.

3. Generate a six to eight point temperature versus resistance curve for each sensor by first letting the sensors and measuring thermometer stabilize at room temperature (about 70°F). Place an ohmmeter across each sensor's leads, and read and record the resistance of each sensor. Do not hold the sensors, as they will pick up heat from your hand, which will change their resistance.

4. Place the sensors and thermometer in an ice bath, and, after they have had time to stabilize, measure and record the temperature and each sensor's resistance. If the sensors cannot be immersed directly in water, place them and the thermometer in a small watertight plastic, as shown in figure 2-39. Remove the air from the bag and close the top with a rubber band. The time required for the temperature of the sensor to stabilize may take a little longer, but the sensors will stay dry.

5. Heat the container of water to approximately 55°F, and immerse the sensors and thermometer in water as described in step 2. Maintain the 55°F temperature for at least two minutes while stirring the water. Make sure that neither the sensors nor the thermometer are touching the side or bottom of the container. Measure and record the temperature and each sensor's resistance.

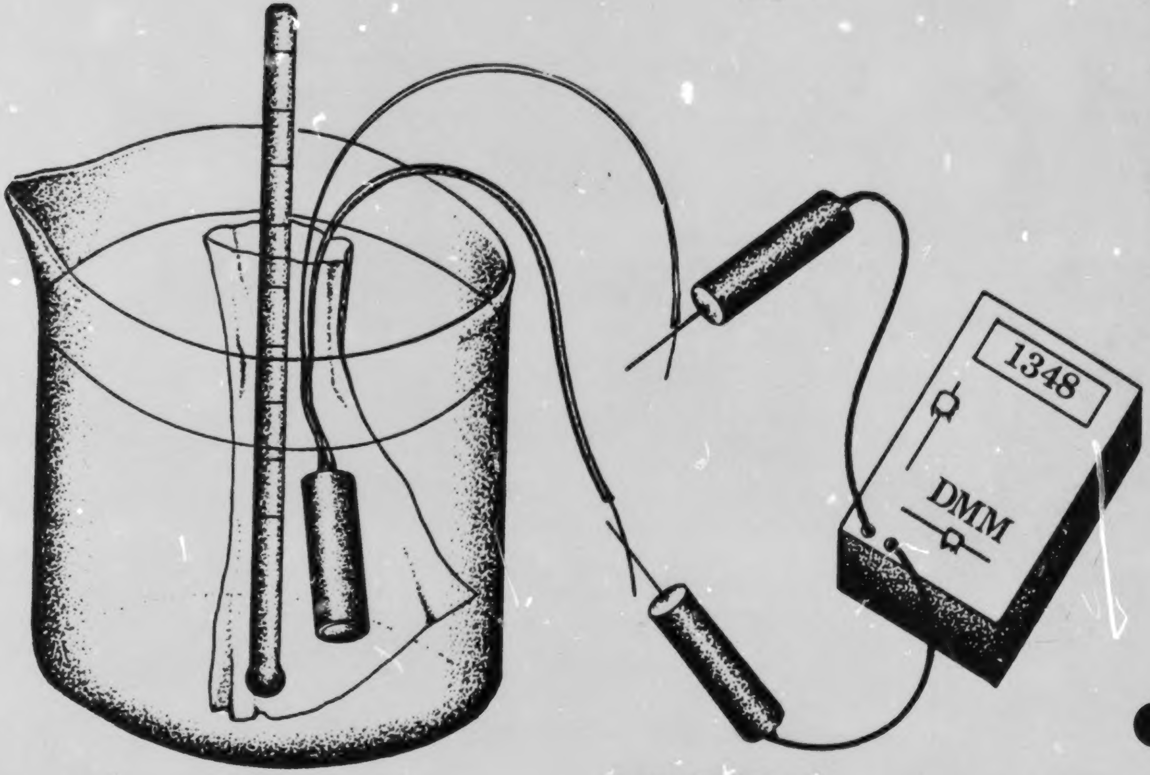


FIGURE 2-39
MEASURING A SENSOR'S RESISTANCE

6. Repeat step 3 with water at about 95°F, 115°F, 135°F, 155°F, and 175°F.

7. Draw each sensor's temperature versus resistance curve on graph paper (semi-log for thermistors and linear for nickel wire and film sensors), and compare the resistances to those specified by the controller manufacturer. Some deviation from the manufacturer's specifications can be expected, due to the test setup and accuracy; however, the difference between similar sensors should be equivalent to less than 1°F.

8. Compare values of like thermistors from the recorded data. What conclusions do you draw from this experience?

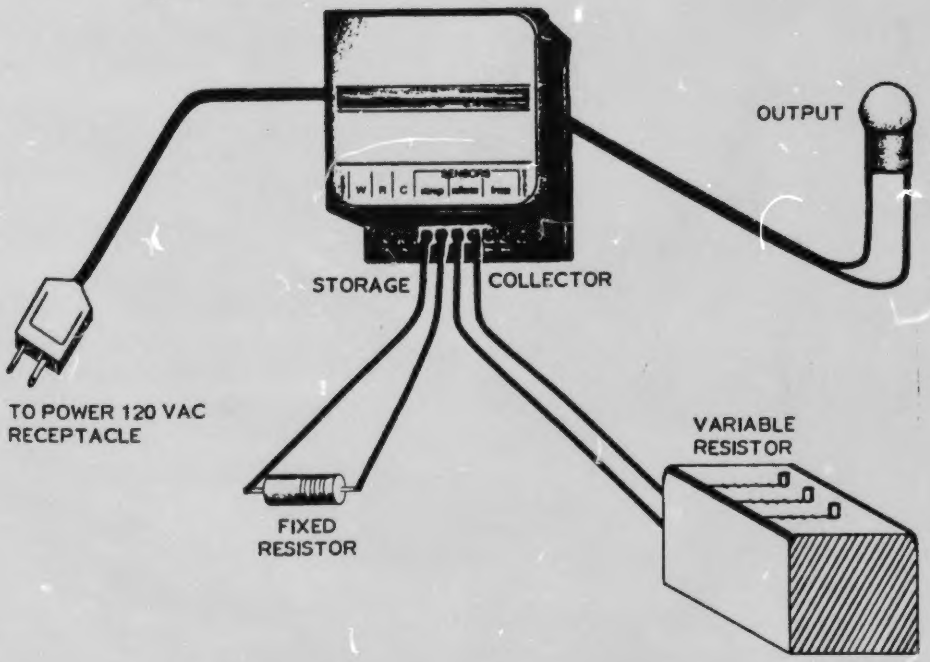
LAB: OPERATIONAL DIAGNOSIS

Lab 10: Differential Temperature Controls - Comparator

Frequently the Differential Temperature Controller does not respond at the desired "temperature on" and "temperature off". Some controllers are factory set at a predetermined "on and off" differential but can be adjusted to change the factory setting. However, the operational characteristics of the controller must be known in order to make the adjustment accurately.

This procedure can also be used to troubleshoot (diagnose) the controller as being acceptable or malfunctioning. Also, it can be seen from this experiment that a device could readily be built that would be a useful tool in controller diagnosis.

1. Connect the variable resistor (Potentiometer) as shown in the diagram below. Potentiometer and fixed resistor should be of a value compatible to the controller being tested.



2. Slowly change the resistance of the potentiometer until the light comes on. You may have to do this several times until you are sure you haven't "overshot" the on point.

3. Unplug the unit; disconnect one wire to the potentiometer and measure the resistance value of the pot at the "on point".

4. Using a temperature/resistance conversion chart, record the "on temperature" of the pot. Also record the temperature value of the fixed resistor. Record the temperature differential "on".

5. Reconnect the pot and change the resistance until the pot is well past the light on position.

6. Slowly change the pot resistance until the light goes off.

7. Repeat steps 3 and 4 and record the "off differential".

8. Compare these values to the manufacturers specifications for the controller.

9. Repeat this experiment by placing the fixed resistor in the collector sensor loop and the pot in the storage loop.

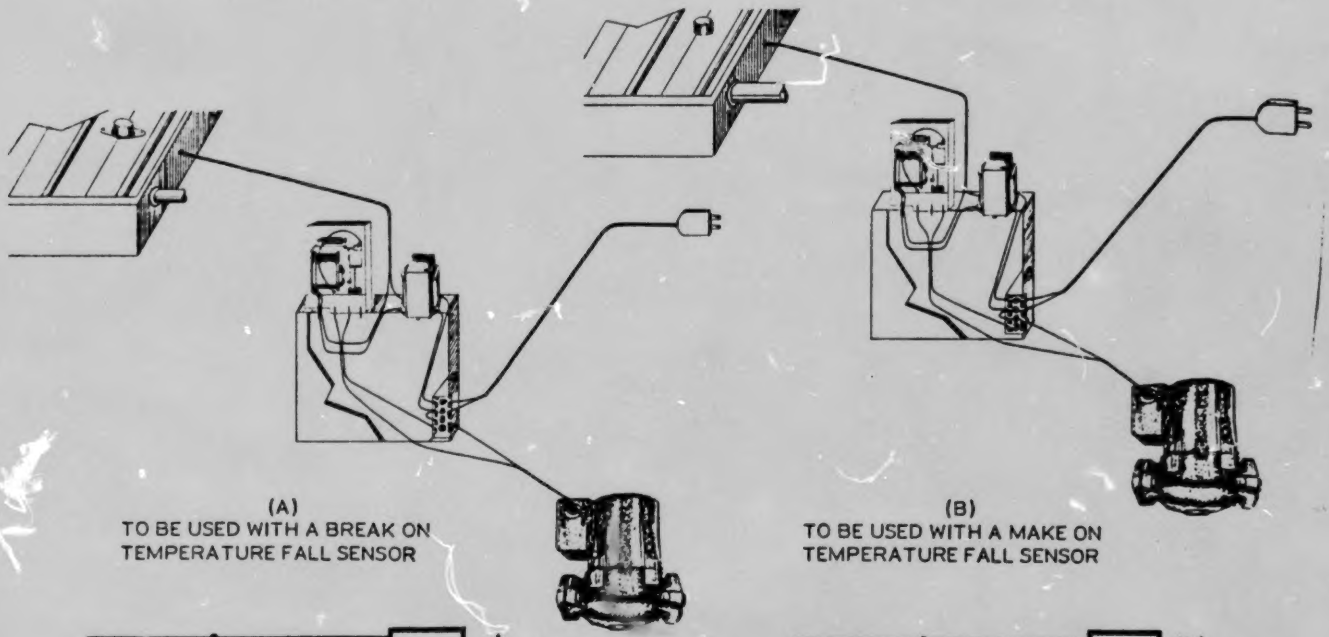
10. If a controller having a variable upper limit is available, this experiment can also reveal the operating characteristics of this type controller. This procedure can also be used to determine freeze protection values in those solid state controllers using this method.

Lab 11: Differential Temperature Controls - Freeze Protection VIII-83

Freeze protection through controller action is a common method used in the industry; however, protection by this method should make provisions for power failure which could make the DTC inoperative, thereby losing the freeze protection.

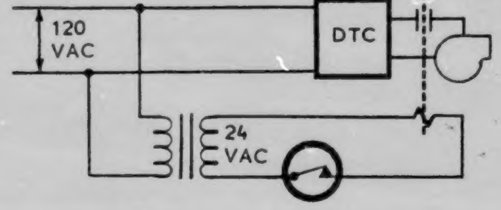
This experiment will assist in developing skills in controllers using these methods of freeze protection.

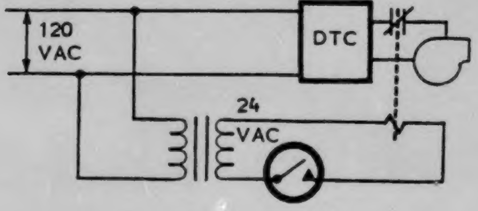
1. Using a thermal switch that opens on temperature fall, wire the controller and pump (or light) as shown in A below.



(A)
TO BE USED WITH A BREAK ON
TEMPERATURE FALL SENSOR

(B)
TO BE USED WITH A MAKE ON
TEMPERATURE FALL SENSOR





2. Simulate freezing conditions by placing the thermal switch in an ice bath. Protect the switch from moisture with a plastic bag.

3. Observe the action of the pump (or light).

4. Using a thermal switch that closes on fall of temperature, wire the system as shown in B above.

5. Repeat steps 2 and 3.

6. Repeat this experiment by wiring each of the following circuits.

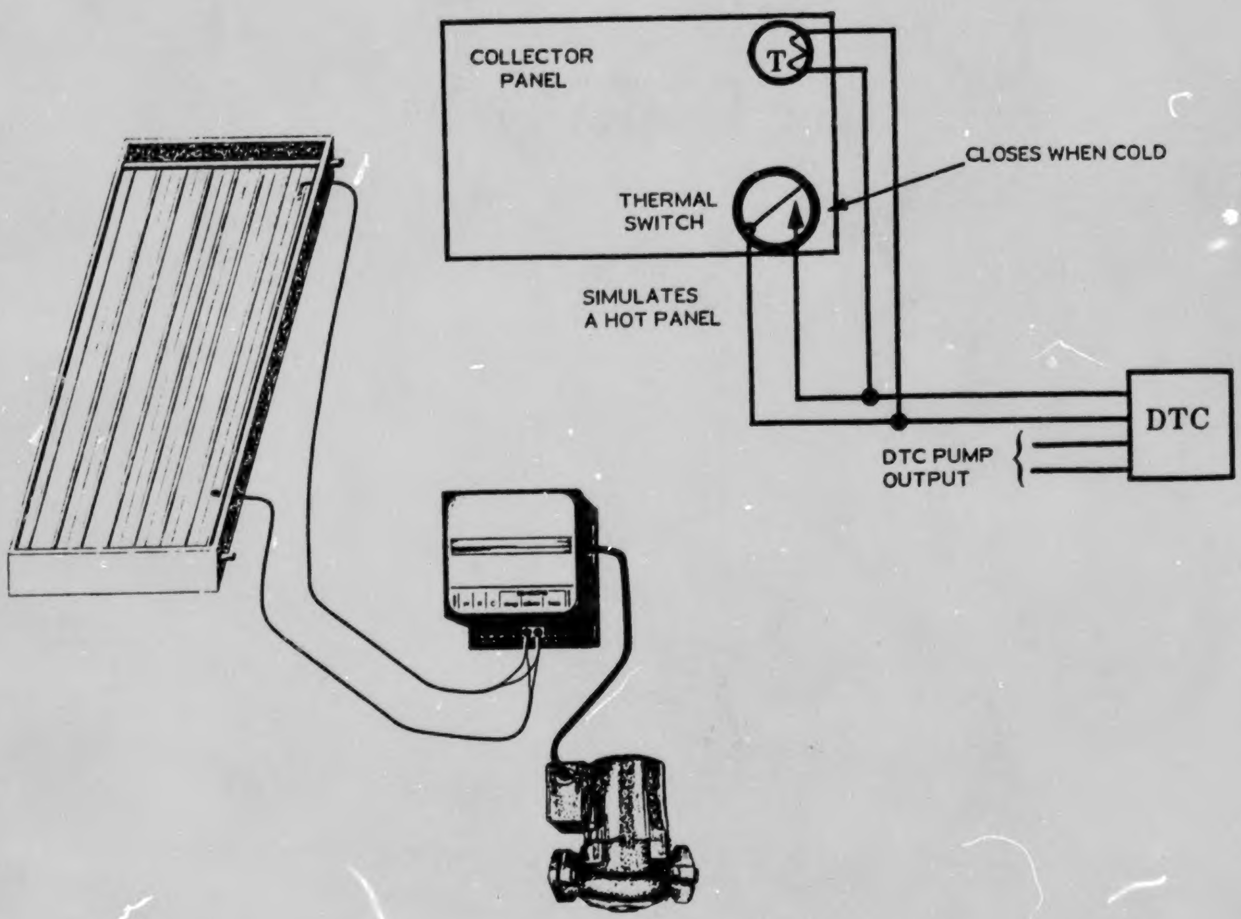

COLLECTOR PANEL
T
CLOSES WHEN COLD
THERMAL SWITCH
SIMULATES A HOT PANEL
DTC
DTC PUMP OUTPUT

FIGURE 2-19
FREEZE PROTECTION BY SHORTING OUT PANEL SENSOR

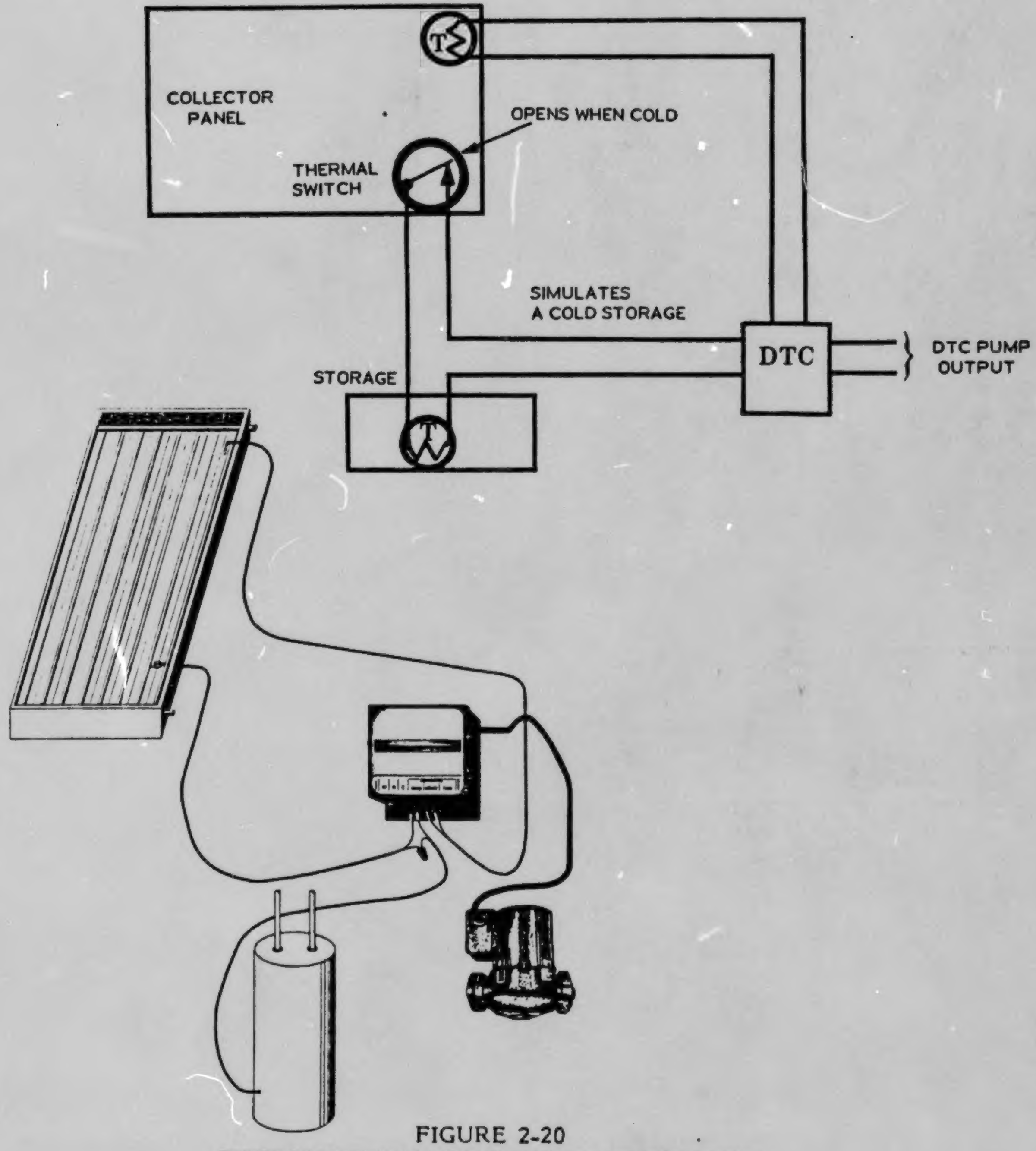

T
COLLECTOR PANEL
OPENS WHEN COLD
THERMAL SWITCH
SIMULATES A COLD STORAGE
STORAGE
T
DTC
DTC PUMP OUTPUT

FIGURE 2-20
FREEZE PROTECTION BY OPENING STORAGE SENSOR CIRCUIT

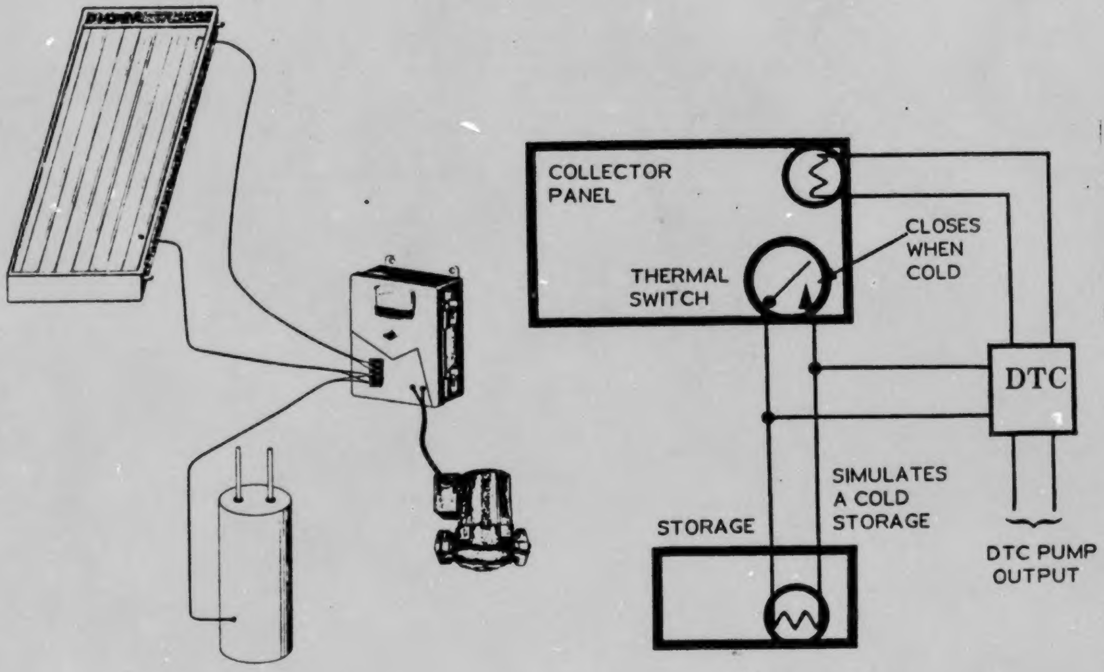
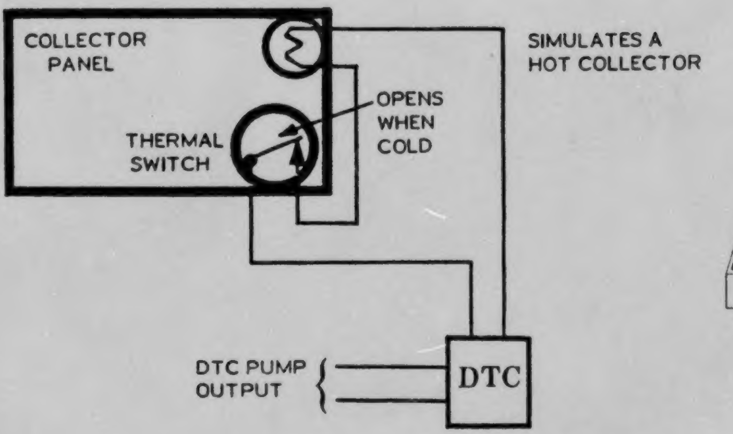

COLLECTOR
PANEL
THERMAL
SWITCH
CLOSES
WHEN
COLD
DTC
STORAGE
SIMULATES
A COLD
STORAGE
DTC PUMP
OUTPUT

FIGURE 2-21
FREEZE PROTECTION BY SHORTING OUT STORAGE SENSOR


COLLECTOR
PANEL
THERMAL
SWITCH
OPENS
WHEN
COLD
SIMULATES A
HOT COLLECTOR
DTC PUMP
OUTPUT
DTC

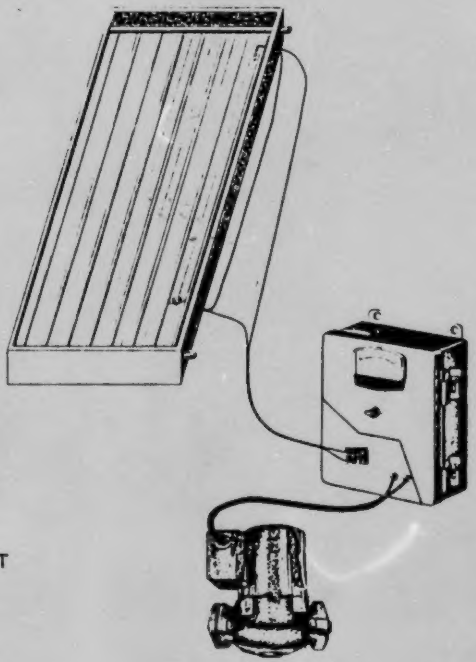


FIGURE 2-22
FREEZE PROTECTION BY OPENING THE PANEL SENSOR CIRCUIT

Lab 12: Differential Temperature Controls - Air Systems VIII-87

A common problem to solar liquid and air systems is a malfunctioning differential controller. Erratic controller behavior can be the result of an imbalance in the resistance of the cable (wires) connecting the controller to the collector plate and storage tank sensors. These sensors usually change resistance value with a change in temperature. The comparator circuit of the controller compares the resistance value of the plate sensor and the tank sensor; therefore, sends a signal to the pump/blower circuit to be on or off, depending upon the preset circuit values. A controller using high resistance value thermistors (sensors), such as 10K ohms, 30K ohms, would usually be insensitive to the resistance of the interconnecting wires. However, a controller such as the Honeywell R7412 which uses 3 K ohm thermistors which increases resistance as temperature increases (as opposed to other sensors which decrease in resistance as temperature increases) can cause erratic operation when the connecting cables are excessively long, or one cable quite a bit longer than the other.

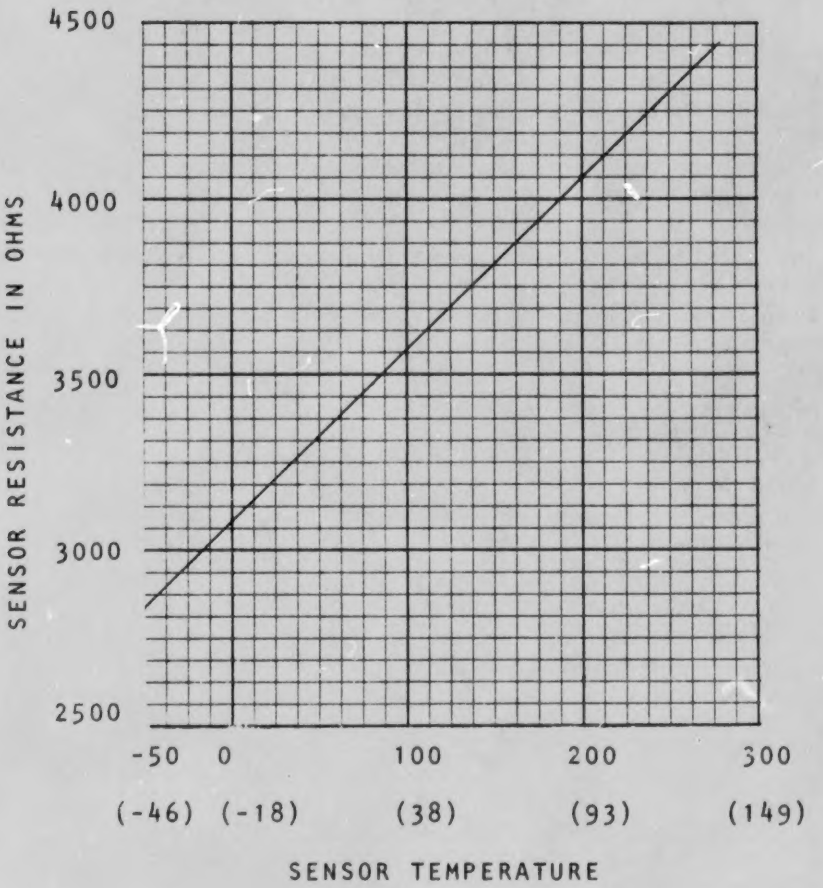
The effects these conditions would have on the controller can be determined using the following procedure:

1. Disconnect the connecting wires from the Low and High sensor terminals at the controller. Be sure and mark them so you know which one is the High sensor lead.

2. Disconnect the connecting wires from the plate and tank sensors. Using a wire nut, connect the interconnecting leads to each sensor together so you can determine the total wire resistance of each pair.

3. At the controller measure the total (out and back) resistance of the connecting pair for the plate sensor and tank sensor. Record the wire resistance for each pair here
   Plate wires ____________
   Tank wires _____________

4. Using the sensor resistance/temperature conversion chart provided, analyze the results and make a recommendation for eliminating system imbalance at the controller.


4500
4000
3500
3000
2500
SENSOR RESISTANCE IN OHMS
-50
0
100
200
300
(-46)
(-18)
(38)
(93)
(149)
SENSOR TEMPERATURE

Lab 13: Auxiliary Systems Interface

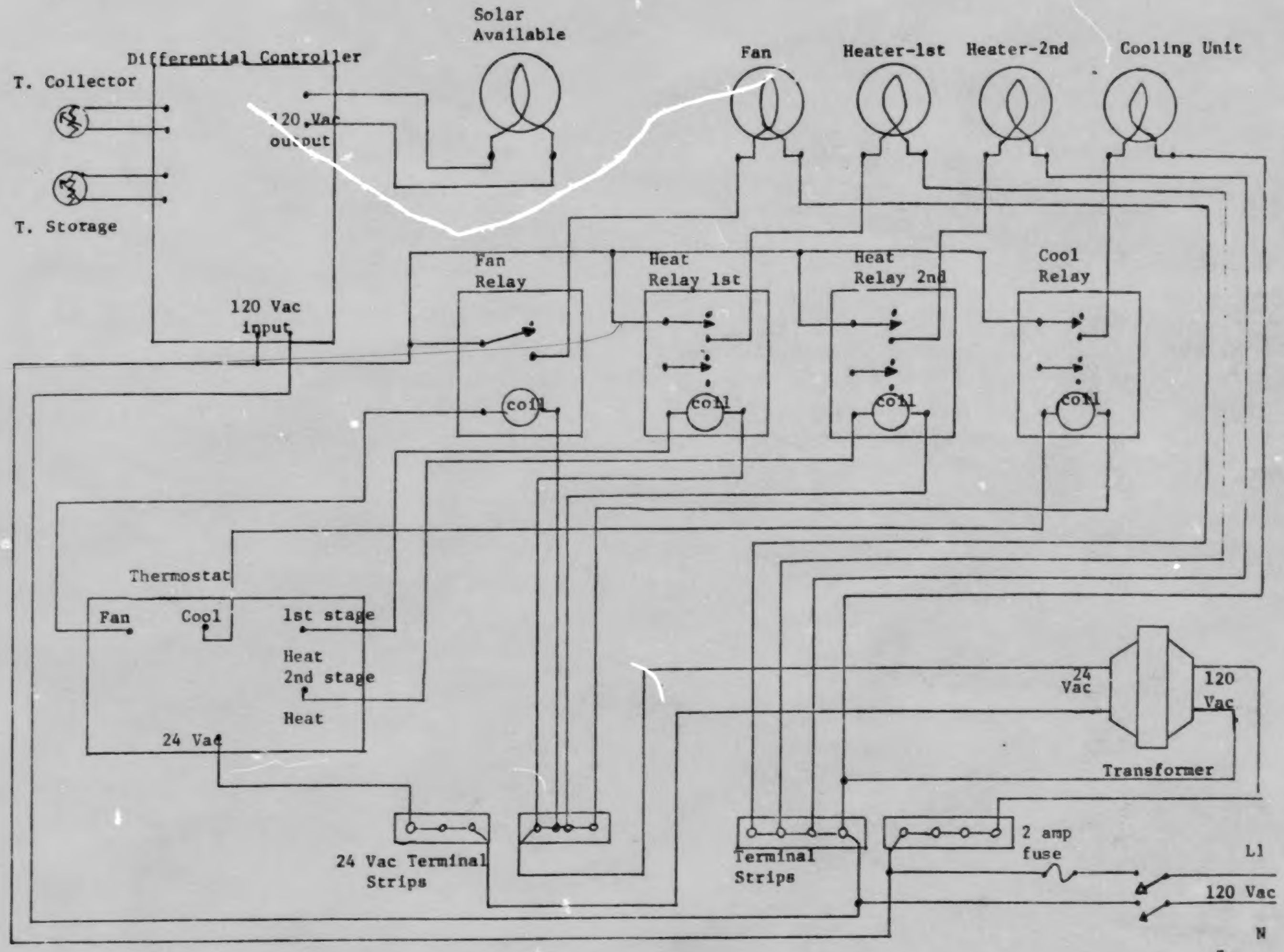
Frequently a very vital part of the Solar system is overlooked. That part is the auxiliary (back-up) system. The technician must have diagnostic skills that will enable him/her to make rational decisions as to which part of the total system is malfunctioning.

Before attempting to troubleshoot complex control systems, which includes auxiliary equipment controls, it would be very helpful if skills were developed in simpler circuits. The following lab will assist in this intermediate step.

1. Using a training board, similar to the one shown on the following page, wire the components.
2. Use an ohm meter to determine if the total circuit has a short circuit; if not, proceed.
3. Draw a latter schematic diagram of the trainer.
4. Connect sensors to the controller and simulate "sun and no sun" conditions through the use of cups of hot and cold water.
5. Operate the thermostat to simulate a call for heat - 1st state, a call for heat - 2nd stage and a call for cooling.
6. Describe in detail the operating sequence of this training simulator.
7. Develop troubleshooting skills by asking the lab attendant to place "faults" in the system, then, using the appropriate tools, diagnose the problems.

LAB: OPERATIONAL DIAGNOSIS

Lab 13: Auxiliary System Interface


Solar Available
Differential Controller
T. Collector
T. Storage
120 Vac output
120 Vac input
Fan
Heater-1st
Heater-2nd
Cooling Unit
Fan Relay
Heat Relay 1st
Heat Relay 2nd
Cool Relay
coil
coil
coil
coil
Thermostat
Fan
Cool
1st stage
Heat
2nd stage
Heat
24 Vac
24 Vac
120 Vac
Transformer
24 Vac Terminal Strips
Terminal Strips
2 amp fuse
L1
120 Vac
N

LAB 13

Lab 14: Diagnostic Approach to Troubleshooting VIII-91

The accomplished diagnostician will have a definite approach to troubleshooting for malfunctioning components. Development of this diagnostic approach requires knowledge in what the system is supposed to do and when it is supposed to happen.

1. Using the Lennox RT5 and EB5 Solar trainers (or similar trainers):
    a. Study the cycle and the effects of the various switches.
    b. List the operational sequencing of the mechanical and electrical components, both solar and auxiliary.

2. Using the Lennox ST-17 (or similar) solar trainer and the student manual, go through the check out procedures. This activity will make you familiar with the trainer.

3. Study the manual for normal operating modes (or construct your own table) and notice the effects of the fault switch on these modes of operation.

4. Place the trainer in a fault position and diagnose the problem using the appropriate tools. Repeat each fault switch for all operating modes.

5. Using data from previous steps and schematic drawing of this system, construct a diagnostic flow diagram.

Lab 15: Fluid Transport Systems

Great emphasis has been placed on the electrical part of the solar system; and properly so since approximately 80% of the system failure can be attributed to electrical components, nevertheless, the mechanical components of the system cannot be overlooked. The pumps, blowers, valves, heat exchangers, etc. all perform a vital function in the system. This lab will assist in developing diagnostic skills in assessing the condition of these components.

1. Using a liquid solar system with a variable speed pump and balancing valves: (allow 15 minutes for system balance to occur).
   a. Open balancing valves and set pump to run at low speed. Record the Δt across the collector array.
   b. Set pump to run at medium speed and record Δt across collector array.
   c. Repeat with pump at high speed.

2. Using knowledge from previous course work, evaluate which pump speed provides best collector performance in efficiency. Which speed would be best suited for the applications of:
   a. Domestic Hot Water
   b. Residential space heating
   c. Swimming pool/spa

3. With pump running at high speed, simulate a badly scaled system by 50% closure discharge side balancing valve and record Δt across collectors. Compare with data from 1C. Analyze the data comparison.

4. Repeat step 3 with pump at low speed.

5. List the system component that would most likely have scaling that could impede fluid flow.

6. Describe what action should be taken to remove scale from system.

7. Using solar air system with damper control:
   a. Simulate damper motor failure or broken linkage by disconnecting damper linkage and restricting air flow. Measure air temperatures and external static pressure of system before disconnecting damper linkage.

  b. Measure external static pressure - E.S.P. - with damper restricting air flow. Also measure change in air temperature.

8. Analyze data from 7 and describe how malfunctioning dampers can effect system performance.

CODES, LEGALITIES, CONSUMERISM, AND ECONOMICS

Semester Hours Credit: 2
Lecture: 2
Lab: 0

Project Director:	Charles G. Orsak, Jr.
Prime Author:	Wayne Silva
Contributing Authors:	Ray Mudrak Bill Bolin Charles Younger

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1181

INTRODUCTION:

The Codes, Legalities, Consumerism and Economics course contains subject matter related to the consumer and legal problems associated with sales, installation, and product requirements of solar energy systems and components.

The intent of this course is to give the student an introduction to the requirements imposed by federal, state, and local governments to assure minimum solar energy system standards and quality. Also, the benefits associated with these requirements such as tax credits will be presented. The depth of coverage and extent of details must be left to the discretion of the instructor of the course. Printed materials, in the form of handouts, will conserve time in many subject areas, therefore leaving more time for classroom/laboratory instruction.

COURSE DESCRIPTION:

This course introduces the applicable codes, legal requirements and responsibilities, consumer protection, and business regulations, and government tax exemptions and credits that affect the solar energy industry. The course will review those regulations imposed on the solar industry before solar energy was introduced and the changes which have taken place to address the solar industry specifically. The course will then address the government's activity in consumer protection through product testing and standard requirements. Finally, the course will evaluate the economics of the solar investment.

COURSE PREREQUISITES:

(1) Solar System Sizing and Design Course

(2) High school business math or equivalent

COURSE OBJECTIVES:

Upon completion of this course, the student should be able to:

(1) Identify and apply the specific Federal, State, and local requirements affecting solar energy.

(2) Discuss and describe legal commitments and responsibilities of the solar technician.

(3) Develop a model warranty that complies with the standards required of solar systems and components.

(4) Determine economics related to the purchase of solar energy systems.

(5) Make a life-cycle-cost analysis of alternative energy systems and state the rationale for a final decision.

(6) Describe the types of liens; what are the implied or explicit responsibilities.

(7) List the qualities and experience expected when selecting a solar contractor.

(8) Develop a model contract indicating the responsibilities of the purchaser and contractor.

(9) Identify potential financial/lending agencies for solar loans.

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OBJECTIVES:

Upon completion of this module, the student should be acquainted with the problems posed by the National Building codes and Uniform Building codes drafted before solar energy became widely used. The module will then address the progress made by the National Code Organizations to address solar specifically.

The student should become familiar with the Uniform Solar Energy Code and its applications.

Upon completion of this module, the student should be able to:

(1) Identify and discuss the problems posed by the National Building Codes and Uniform Building Codes drafted before solar energy became widely used.

(2) Describe progress made by the National Code Organizations to address solar specifically.

(3) Demonstrate familiarity with the Uniform Solar Energy Code and its applications.

(4) Obtain the necessary permits required by state and local authorities for the construction of a solar energy system.

REFERENCES:

(1) Model Document for Code Officials on Solar Heating and Cooling of Buildings, Third Draft, DOE/CS/4281-1, prepared by CABO, BOCA, ICBO, NCSBCS AND SOCC.

(2) Uniform Solar Energy Code, 1979 Edition, International Association of Plumbing and Mechanical Officials, 5032 Alhambra Avenue, Los Angeles, California

(3) Wakesmen, D., Holton, J., Environmental and Safety Considerations for Solar Heating and Cooling Applications, NBSIR 78-1532, September 1978.

(4) Riley, J.D., Odlend R., Baker, H., Standards, Building Codes and Certification Progress for Solar Technology Applications, SER/TR 53-095, July 1979.

(5) Intermediate Minimum Property Standards Supplement, Solar Heating and Domestic Hot Water Systems, 1979 Edition, GPO Order No. SN-023-000- 90161-7.

(6) ASHRAE Standard 55-74, Thermal Environment of Conditions for Human Occupancy, ASHRAE, N.Y., N.Y.

(7) Bluston, Lewis, Licenses, Permits and Inspections, How to Subcontract Your House: Building and Remodeling, Tab Books, Blue Ridge Summit, Pennsylvania 17214, 1976.

RATIONALE:

Obtaining the required permits and licenses and adhering to the state and local codes is essential to the initiation, progress and completion of any construction project. Solar projects require more attention and the proper coordination with the state and local authorities to prevent construction delays while assisting the contractor in preparing the necessary documentation and scheduling required for site inspections.

UNIT TITLES:

(1) Uniform Solar Energy Code Book

(2) Plumbing, Electrical and Structural Codes

(3) OSHA

(4) HUD Minimum Property Standards for Solar

VOCABULARY:

Code Associations:

BOCA - Building Officials and Code Administrators International, Inc.

CABO - Council of American Building Officials

ICBO - International Conference of Building Officials

NCSBCS - National Conference of State on Building Codes and Standards, Inc.

SBCC - Southern Building Code Congress International, Inc.

OSHA - Office of Safety and Health Administration

HUD - U.S. Department of Housing and Urban Development

Licenses
Permits
Codes
Plans
Inspections

Enforcement Agency
Electrical
Mechanical
Plumbing
Pipe Fitter

Reference 1, 2

Review Complete Documents

Instructor

Solar Energy Code development has made major advances in order to define and stimulate the solar industry. The instructor should review before and after results and then dwell on the present solar codes.

Unit 1. Uniform Solar Energy Code Book

- A. Describe the problems posed by the National Building Code and Uniform Building Code which were not drafted with solar energy uses in mind
- B. Discuss in detail the Uniform Solar Energy Code and its possible applications
- C. Discuss and compare the effects of the Model Document for Code Offices on Solar Heating and Cooling of Buildings

Reference 1, pp. 1-7
2, Chap. 1
4, All
5, Chap. 1
7, All

Instructor

Address the national, state, and local codes for the three trades. Require local identification of permit agencies. Circuit courts and county commissioners usually handle the permits, licenses, and inspections. You may obtain these and use as handouts or assign students to obtain.

Unit 2. Plumbing, Electrical, and Structural Codes

- A. Discuss the applications of these codes in general
- B. Investigate the codes that are specific to solar installations
- C. Determine the type of permits required and the agency which issues the permits

References 6, All
7, p. 46

Unit 3. OSHA

- A. Define and describe agency function
- B. Describe the OSHA regulations applicable to solar system installations and operations
- C. Discuss potential problems with implementation

Reference 5

Unit 4. HUD Minimum Property Standards for Solar
- A. Demonstrate the use of the minimum property standards
- B. Discuss limitations and weaknesses

STUDENT ACTIVITY

Exercise

Assignment

Given a building plan, solar schematic, or blueprint, the student should:

(1) Determine what permits are required and the local agency issuing them.

(2) List the appropriate sections from the HUD Minimum Property Standards document that is applicable to this project.

(3) List potential, if any, conflicts with OSHA guidelines.

(4) Determine whether or not the system installation and structure conforms to the Uniform Solar Energy Code.

MODULE: OVERCOMING LEGAL BARRIERS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Obtain documentation and history related to previous solar energy construction projects.

(2) Use the Federal and state legislation as tools to overcome legal barriers.

(3) Overcome the lack of solar knowledge by officials and inspectors by identifying their needs before they ask the question.

REFERENCES:

(1) Eccli, Eugene, "Some Problems to Overcome - Codes, Appeals, Public Acceptance and Contractor Resistance", *Low Cost Energy - Efficient Shelters*, Rodale Press, Pennsylvania, 1976, pp. 31-39.

(2) Wallenstein, Arnold R., *Barriers and Incentives to Solar Energy Development, An Analysis of Legal and Institutional Issues in the Northeast*, Dec. 1978, DOE/EM-78-C-01-42-14, pp. 57-75.

(3) *Model Document for Code Officials on Solar Heating and Cooling of Buildings*,, Third Draft, DOE/CS/4281.

(4) U.S. Department of Energy, *Commercial Solar Heating and Cooling DemonstrationProject Summaries*, DOE, Washington, D.C.

(5) U.S. Department of Housing and Urban Development, *Residential Solar Heating and Cooling Demonstration Project Summaries*, Cycle 1 through 5, Washington, D.C.

(6) Myers, Barry Lee, "Solar Access Rights in Residential Developments", *The Practical Lawyer*, March 1, 1978, pp. 13-20.

(7) Wells, Malcolm and Irwin Spetgang, "Sunlight and the Law", *How to Buy Solar Heating Without Getting Burnt*, Rodale Press, Emmaus, Pennsylvania, 1978, pp. 189-214.

MODULE: OVERCOMING LEGAL BARRIERS

RATIONALE:

When dealing with local contractors and/or state and local inspection officers, it is to the advantage of the owner or general contractor to be aware of existing projects and legislation applicable to the current project. Presenting facts of past experiences will assist the local contractors and inspectors in understanding the current project. Providing them with information will assist in identifying problems in the early stages of the project and build confidence and cooperation in the project.

UNIT TITLES:

(1) Federal/State Legislation

(2) Contractor Resistance

(3) Codes and Inspection

(4) Rights to the Sun

VOCABULARY:

Mechanical
Electrical
Plumbing
Structural
Safety
Inspection
Solar Access
Restrictive Covenants
Easements
Zoning Ordinance

Reference 2, pp. 57-75 4, All 5, All Instructor Make contact with the Regional Solar Energy Center: (1) Northeast Solar Energy Center, Boston; (2) Southern Solar Energy Center, Atlanta; (3) Mid-American Solar Energy Center, Minneapolis; (4) Western Sun, Portland. They can provide information on legislation and projects in the region you are in.	Unit 1. Federal/State Legislation A. Discuss the Federal and State legislation designed to promote the research, development, and testing of solar energy systems and equipment B. Define the Solar Energy Information Data Bank and describe its function and services C. Describe the Federal specifications for performance criteria of solar equipment D. Identify Federal solar energy demonstration projects E. Discuss State and local solar energy activity related to performance standards of solar energy equipment, research, demonstration projects, and incentive programs
Reference 1, pp. 31-39	Unit 2. Contractor Resistance A. Identify the causes of contractor reluctance to build solar housing B. Discuss ways to promote public acceptance of solar structures
Reference 1, pp. 31-39 2, pp. 57-75 3, All	Unit 3. Codes and Inspection A. Discuss the legal barriers posed by codes which act as barriers to solar B. Describe the inspection procedure a solar system would undergo

Reference 6, pp. 13-20
7, pp. 189-214

Instructor: Restrictive Covenants drafted by developer may restrict the use of community buildings; plans must be submitted for approval; zoning ordinances regulate type, size, and location of the building. These may limit the solar windows, restrict the shape of building, or prohibit mechanical equipment on the roof.

Unit 4. Right to Sun

A. Describe the existing property law and how it relates to solar energy applications

B. Discuss the problems of implied easement rights to light and air

C. Discuss how to take advantage of existing easement doctrines to create express agreements that provide the solar homeowner with protection by affirmative or negative easements

STUDENT ACTIVITY

Exercise

ASSIGNMENT

Given a proposed solar project with a system schematic and a specific location, the student should:

(1) List the applicable documentation of similar projects located in a general region.

(2) List the Federal or State legislation affecting the project.

(3) Prepare a list of points to be discussed with the contractor or inspector.

(4) Determine if any local or community covenants or zoning ordinances restrict the project.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe and prepare a model contract.

(2) Discuss the contractor's responsibilities and liabilities.

(3) Describe the legal position of sub-contractors.

REFERENCES:

(1) Wallenstein, Arnold R., Barriers and Incentives to Solar Energy Development, An Analysis of Legal and Institutional Issues in the Northeast, Dec. 1978, DOE/EM-78-C-01-42-14, pp. 57-75 and 79-86.

(2) Model Document for Code Officials on Solar Heating and Cooling of Buildings, Third Draft, DOE/CS 4281-1, prepared by CABO, BOCA, ICBO, NCSBCS and SBCC.

(3) Myers, Barry Lee, "Solar Access Rights in Residential Developments", The Practical Lawyer, March 1, 1978, pp. 13-20.

(4) Wells, Malcolm and Irwin Spetgang, "Sunlight and the Law", How to Buy Solar Heating Without Getting Burnt, Rodale Press, Emmaus, Pennsylvania, 1978, pp.189-214.

(5) Robbins, Richard L., "Law and Solar Energy Systems: Legal Impediments and Inducements to Solar Energy Systems", Solar Energy 18: 371-79, Elmsford, N.Y. 10523: Pergamon Press, 1976.

(6) Eccli, Eugene (ed.), "Some Problems to Overcome - Codes, Appeals, Public Acceptance, and Contractor Resistance, Low-Cost, Energy-Efficient Shelter, Rodale Press: Emmaus, Pennsylvania, 1976, pp. 31-39.

(7) Bluston, Lewis, How to Subcontract Your House: Building/Remodeling, Tab Books, Blue Ridge Summit, Pennsylvania, 17214, 1976, pg. 195.

(8) Wells, Malcolm, and Irwin Spetgang, "Contracts and Contractors", How to Buy Solar Heating Without Getting Burnt, Rodale Press, Emmaus, Pennsylvania, 1978, pp. 159-188.

(9) Watson, Donald, Building a Solar House, Designing and Building a Solar House, Garden Way Publishing, Charlotte, Vermont 05445, 1977, pp. 159-203.

(10) Watkins, A.M., Home Improvements and Remodeling, The Home Owner's Survival Kit, Hawthorn Books, New York, 1971, pp. 165-192.

(11) Porter, Sylvia, "Or Should You Build?", The Money Book, Doubleday & Company, Garden City, New York, 1975, pp. 581-593.

(12) "What You Should Know About Contractors", How to Live on Your Income, Readers Digest, Pleasantville, New York, 1970, pp. 179-191.

(13) "More on Mechanics Liens, Stop Notices and the Like", 54 California Law Review, 179-189, 192-207, 1966.

RATIONALE:

The first contact with a contractor is through a project specification and construction drawing which describes what the project will require in material and labor. It will be advantageous to screen several contractors to obtain the best qualified contractor at the best price. After the contractor is selected, a contract describing the responsibilities of each party [the owner and contractor(s)] is prepared. This contract will state the general scope of the project: the requirements that must be met by the contractor, material and equipment to be used, labor and scheduled payment agreement, and conditions and provisions. The detail of each of these steps varies with the size of the project, but in essence they exist for all projects.

UNIT TITLES:

(1) Contracts

(2) Contractors: Responsibilities/Liabilities

(3) Sub-Contractors

(4) General Legal

VOCABULARY:

Contractor

Progress Payment

Estimate

Contract

Sub-Contractor

Reference 1, Chap. 2 5, pp. 371-79 7, p. 175 8, pp. 159-188 __Instructor__: Provide an outline of a standard contract on a viewgraph or chalkboard. See Reference. 7 & 8. Break into sections and describe contents for various size projects. Show effects of different statements or provisions.	Unit 1. Contracts A. Analyze standard contracts in the construction industry used by architects and contractors B. Evaluate the legal significance of various conditions and provisions contained in these contracts C. Describe how to amend or modify standard contracts to meet your specific needs D. Develop a model contract for the construction of a solar home or remodeling one to accept solar systems E. Understand pitfalls applicable to all contracts and the legal consequences of breach of contract
Reference 7, All 8, pp. 159-188 9, pp. 159-203 12, pp. 179-191 13, pp. 192-207 __Instructor__: After discussion of contractors and qualifications, provide handout of checklist for contractors. Excellent checklists have been prepared recently by the Regional Solar Energy Centers; make contact and obtain.	Unit 2. Contractors A. Develop a checklist to determine whether a contractor will be reliable B. Describe how to set up competitive bidding among contractors to construct a solar home C. Describe licensing requirements for contractors at the state level
Reference 7, All 12, pp. 179-191	Unit 3. Sub-Contractors A. Describe the importance of the role of sub-contractors in construction projects and contractual provisions permitting the use of subcontractors B. Understand the purpose of labor and material payment bonds and performance bonds C. Describe the insurance responsibilities when sub-contractors are involved

Unit 4. General Legal
- A. Progress payments
  - 1. Show the advantages of making progress payments to a contractor
  - 2. Develop a model progress payment schedule for the construction of a solar home
  - 3. Be aware of the legal consequences of overpayment during construction
- B. Architects
  - 1. Describe the role and function of architects in building or remodeling a home
  - 2. Discuss licensing criteria for architects and their general educational and training backgrounds
  - 3. Provide criteria for evaluating the effectiveness of an architect for solar design and applitions
- C. Zoning

  Describe how a carefully drafted solar zoning ordinance has great potential for stimulating solar development

STUDENT ACTIVITY

Exercise

ASSIGNMENT:

(1) Develop a model contract for the construction of a solar home and a remodeling project.

(2) Develop the schedule, material, and labor requirements and the type of payment agreement.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Discuss the difference in warranties (implied, expressed, limited, plain language).

(2) Know the consumer rights under the different warranties.

(3) Understand potential remedies for breach of expressed or implied warranties under state and federal law.

(4) Develop a model warranty.

(5) Know the advantages and disadvantages of contractual warranties, common law warranties, statutory warranties and standard builders' warranties.

REFERENCES:

(1) Wallenstein, Arnold, Barriers and Incentives to Solar Energy Development, December 1978, DOE-EM-01-4274, pp. 33-49.

(2) "The Solar Shopper, Practical Guide to Solar Homes", Hudson Home Guides, Los Altos, California, February 1978, pp. 115-139.

(3) Rothchild, J., and F. Tenney, "How to Buy Solar", The Home Energy Guide, Ballantine Books, 1978, pp. 155-179.

RATIONALE:

Most homeowners are aware of warranties associated with new home/building construction and the installation of solar energy equipment. All new home or renovation construction projects carry at least a one-year common law warranty against defects and errors without the need for a written statement. In addition, equipment and appliances such as solar energy systems, have warranties which last one to ten years. There are many different types of warranties which have different conditions. These conditions place restrictions on use, define failures, and describe the responsibility of the manufacturer, installer, and owner. Knowing the differences of the various types of warranties will enable the consumer to buy the most practical solar energy system and not get burnt.

MODULE: WARRANTIES

UNIT TITLES:

(1) Types/Meanings
(2) Advantages/Disadvantages
(3) Develop a Model Warranty
(4) Home Owners Warranty

VOCABULARY:

Expressed Warranty
Implied Warranty
Limited Warranty
Plain Language Warranty
Standard Builder Warranty
Common Law Warranty
Contractual Warranty
Loopholes
Liability
Product Certification

Reference 1, pp. 33-49 2, pp. 115-39 3, pp. 155-79 Instructor: Obtain example warranties for various collector manufacturers. Use these throughout the module.	Unit 1. Types/Meanings A. Identify products and manufacturers which provide express warranties B. Discuss potential problems and loopholes in existing warranties C. Explain consumer rights under the Implied Warranty of Merchantability and the Implied Warranty of Fitness for Use D. Describe potential remedies for breach of express or implied warranties under state and federal law
Reference 2, pp. 115-39 3, pp. 155-79	Unit 2. Advantages/Disadvantages Describe the advantages and disadvantages of contractual warranties, common law warranties, statutory warranties, and standard builder warranties
	Unit 3. Model Warranty Develop a model warranty to be inserted in a building contract
References 2, pp. 115-39 3, pp. 155-79	Unit 4. Home Owners Warranty Identify the types of warranties that may be applicable to solar home construction
STUDENT ACTIVITY	ASSIGNMENT:
Exercise	Given four warranties, the student should: (1) Identify the type and give reason. (2) Develop a model warranty for a total solar project.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Know the legal significance of a lien.

(2) Know the difference between a statutory lien and a common-law lien.

(3) Know how to avoid subcontractor and mechanics liens.

(4) Understand the purpose and consequence of a "Stop Notice".

REFERENCES:

(1) Wells, Malcolm and Irwin Spetgang, "The Sun Isn't Free", *How to Buy Solar Without Getting Burnt*, Rodale Press, Emmaus, Pennsylvania, 1978.

(2) Bluston, Lewis, *How to Subcontract Your House: Building/Remodeling* Tab Books, Blue Ridge Summit, Pennsylvania, 1976.

(3) "More of Mechanics Liens, Stop Notices and the Like", 54 *California Law Review*, 179-189, 192-207, 1966.

RATIONALE:

Knowing what construction liens are and how to avoid or apply them is essential for the homeowner or contractor. A realistic approach to every construction project must be taken and a lien or its counterpart, the stop notice, are legal mechanisms which must be used with forethought.

UNIT TITLES:

(1) Types

(2) Significance and Responsibilities

VOCABULARY:

Common Law Lien

Statutory Lien

Mechanics Lien

Stop Notice

MODULE: LIENS

Reference 1, All
2, All
3, pp. 192-206

Unit 1. Types
- A. Discuss the various types of liens and who can initiate them
- B. Discuss how to avoid subcontractor and mechanics liens in construction projects
- C. Describe how a lending institution can protect you from unwanted liens

Reference 3, pp. 192-206

Instructor: The references provide good descriptions and examples of each lien

Unit 2. Significance and Responsibilities
- A. Discuss the legal signifi- of a lien and how they become attached to property
- B. Define the purpose and legal significance of a "Stop Notice"

STUDENT ACTIVITY

Exercise

ASSIGNMENT:

(1) List the type of liens applied to a solar energy project.

(2) As a contractor describe how to avoid using a lien.

(3) As an owner, issue a stop notice and defend this action.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Discuss the buying and maintaining of solar systems.

(2) Describe consumer product/satisfaction functions.

(3) Discuss detailed financial considerations involving solar systems.

REFERENCES:

(1) Model Document for Code Officials on Solar Heating and Cooling of Buildings, Third Draft, prepared for DOE by CABO, BOCA, ICBO, NCSBCS, SBCCI, Document No. DOE/CS/42 31-1.

(2) California Business and Professions Code, Section 17,500.

(3) Silva, John, Fraud and Advertising, Justice for California Consumer, Sacramento, 1980.

(4) SEIA Certified Thermal Performance Rating Standard for Solar Collectors, SEIA Product Certification Standard 1-79, SEIA, Washington, D.C.

(5) Guidelines for Certification of Solar Energy Equipment, June 1978, Solar Energy Office, Energy Alternatives Division, State of California Energy Resources Conservation and Development Commission, Sacramento, California.

(6) Installation Guidelines for Solar DHW Systems, HUD/DOE, Washington, D.C.

(7) Solar Legislation, May 1980, U.S. Department of Housing, Washington, D.C.

(8) Rothchild, John and Frank Tenney, The Home Energy Guide: How to Cut Your Utility Bills, Ballantine Books: New York, 1978, pg. 247.

(9) Eccli, Eugene and Sandra, Save Energy, Save Money!, Community Services Administration: Washington, D.C. 20506 (May be obtained from the Consumer Information Center: Pueblo, Colorado 81009, No. 664F), May 1977, p. 48.

(10) *How to Understand Your Utility Bill*, Office of Public Affairs, U.S. Department of Energy, Washington, D.C. 20585 (May be obtained from the Consumer Information Center, Pueblo, Colorado 81009, No. 600F), 1976, p. 6.

(11) *Energy Savings Through Automatic Thermostat Controls*, Energy Research and Development Administration, Office of Public Affairs, Washington, D.C. 20545 (May be obtained from the Consumer Information Center, Pueblo, Colorado 81009, 601F), 1976, p. 6.

(12) *How To Save Money By Insulating Your Home*, Office of Energy Conservation, Federal Energy Administration, Washington, D.C. 20461 (May be obtained from the Consumer Information Center, Pueblo, Colorado 81009, No. 603F), July 1977, p. 22.

(13) *Tips for Energy Savers: In and Around the Home, On the Road, In the Marketplace*, Energy Research and Development Administration, Federal Energy Administration, Washington D.C. 20461 (May be obtained free from the Consumer Information Center, Pueblo, Colorado 81009, No. 606F), 1977, p. 46.

(14) *65 Ways to Save Natural Gas*, U.S. Department of Energy, Office of Public Affairs, Washington, D.C. 20585 (May be obtained from the Consumer Information Center, Pueblo, Colorado 81009, No. 595F), 1977, p. 16.

(15) *In the Bank or Up the Chimney?*, Consumer Information Center, Pueblo, Colorado, No. 063F, 1975, p. 70.

(16) Spies, Henry, et al, *350 Ways to Save Energy and Money in Your Home and Car*, New York: Crown, 1974.

(17) Morrell, William, *The Energy Miser's Manual*, Eliot, M.E.: The Grist Mill Publication.

(18) "Heat Saving Ideas", *Popular Mechanics* 142, 1974, pp. 142-56, 1975.

(19) *The Energy Savings Guide Book*, Electrical Industries Association, 6055 E. Washington Blvd., Los Angeles, California 90040, (213) 724-4314, 1973, p. 12.

(20) "Ten Ways to Save Energy", *House and Garden Magazine*, September, 1972.

(21) *Eleven Ways to Reduce Energy Consumption and Increase Comfort in Household Cooling*, Office of Consumer Affairs, Washington, D.C. 20506, 1971, p. 20, U.S. Government Printing Office, Washington, D.C. 20402, No. 0303-0876.

(22) "Heating and Insulating the Home", *Consumer Reports*, October, 1971, pp. 595-599.

(23) *Energy: Less Is More*, 1974, 16 mm color film, 18 minutes, Church Films, Los Angeles, California.

RATIONALE:

People buy solar energy for many reasons. By far the most popular and most important reason for buying solar is that it can be a good long-term investment. By reducing the need for purchased energy, a solar system can save you money. But in order to save money, the solar system must perform adequately for a number of years. The system owner must weigh all the factors involved in good performance and long life before it is determined which system is best suited for the individual making the investment. After obtaining this information, the system owner then must take advantage of all the tax credits and incentives provided.

UNIT TITLES:

(1) Buying, Evaluating, and Maintaining

(2) Consumer Concerns

(3) Detailed Financial Matters

VOCABULARY:

Audit

Tax Credit

Tax Deduction

Return on Investment

Life Cycle Cost

Annual Energy Savings

Fuel Dollar Savings

Initial Cost

Down Payment

Interest Rate

Escalation Rate

Maintenance Cost

System Life

References 1-7

Instructor: Many analytical and economical tools are available to use for calculating the solar economics. The Regional Solar Energy centers will provide great details on problem maintenance, lending institutions, and products available in their region.

It may be to your advantage to have a special instructor come in for one day to discuss life cycle cost analysis

Also, manufacturers' representatives will be glad to appear and discuss their products.

Unit 1. Buying, Evaluating, and Maintaining

A. Determine which system and components are best suited for the individual solar investment

B. Discuss the various financial options available for the purchase of solar energy systems and equipment

C. Identify and resolve many problems, such as advertising, product evaluation, durability

D. Discuss the applicable Federal Trade Commission, Postal Regulations, and Business and Professional Code concerning sales and advertising of solar products

E. Evaluate performance, features, and options of various solar products

F. Evaluate the manufacturers by product performance, years in the field, past activity, financial stability, and customer service

G. Make cost comparisons for various models of solar

H. Define the required maintenance of various solar systems and ways to minimize major repairs

I. Describe how to deal with solar manufacturers and installers when repair problems arise

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Unit 2. Consumer Concerns

A. Determine and maximize savings through conservation, energy savings devices, home installation, and use of energy efficient appliances

B. Perform a complete home energy audit defining energy use and cost

C. Determine energy demand according to specific energy system and determine the effect of installing insulation, weather stripping, and other energy conserving products, and limiting the demand by controlled use

D. Calculate and compare the cost of force home energy systems

E. Calculate and determine the cost of effectiveness of the different methods and techniques of conserving energy

Unit 3. Detailed Financial Matters

A. Determine the annual cash flows of solar versus non-solar systems

B. Develop a life cycle cost analysis data sheet and be able to compute the true annual cost of a solar energy system

C. Identify and discuss insurance problems posed by solar systems

D. Identify which states offer tax incentives or credits for solar energy systems and energy conserving devices

E. Calculate how the combined state and federal tax credits reduce cost of solar energy systems and energy saving devices

F. Describe the property tax consequences of solar energy systems installations

G. Compute the added property value to a home using solar energy systems and the effect on property tax and resale value

STUDENT ACTIVITY

Exercise

ASSIGNMENT:

Given plans for a conventional house, the student should:

(1) Perform an energy audit and identify energy saving through conservation and solar.

(2) Estimate the cost of the energy savings and compare them with the conventional house cost.

(3) Use a life cycle cost analysis developed during the module and determine the cost effectiveness of each energy saving measure individually and collectively.

(4) Calculate the savings as a result of tax credits and incentives from the state and federal governments.

(5) Repeat life cycle cost analysis with tax credits.

CODES, LEGALITIES, CONSUMERISM, AND ECONOMICS

Representative Pre-Tests and Post-Tests

CODES, LEGALITIES, CONSUMERISM AND ECONOMICS

PRE-TEST

Directions: Circle the answer or answers you believe to be correct.

1. To improve solar consumerism, the solar industry must devise and implement __________:

   a. new product lines
   b. major cost reduction programs
   c. innovative sales techniques
   d. simpler control devices

2. The __________ method of economic evaluation finds the interest rate for which lifetime dollar savings are just equal to the lifetime dollar costs:

   a. life-cycle cost
   b. net benefits
   c. benefit/cost
   d. internal rate of return

3. The __________ of utility companies may benefit solar users whose needs for supplemental energy sources fall within qualifying amounts:

   a. peak demand rate
   b. lifeline rate
   c. time-of-day rate
   d. interruptible rate

4. Insofar as applicable, the __________ apply to active and passive solar energy systems that utilize building elements, mechanical subsystems, or combinations thereof:

   a. Uniform Solar Energy Code
   b. HUD Intermediate Property Standards For Solar Systems
   c. Model Document For Code Officials
   d. Code Manual For Passive Solar Design

5. A large fraction of the value of solar equipment is attributable to __________:

   a. direct labor costs
   b. special materials costs
   c. complex fabrication procedures
   d. specialized control devices

6. A __________, by economic definition, means government action which provides income given to a person or group to support and encourage activities that are deemed beneficial to the public:

   a. grant
   b. subsidy
   c. tax credit
   d. low-interest loan

7. Which of the following are necessary for consumer protection in dealing with contractors __________:

   a. check the contractor out
   b. make the contractor bid competitively
   c. don't overpay the contractor during construction
   d. all of the above

8. A consensus within the solar industry has not been reached on what constitutes __________ solar system:

   a. an ideal
   b. an adequate
   c. an aesthetically appealing
   d. a properly sized

9. A __________ stipulates a minimum rate of return which must be recovered on an investment over and above other investment costs:

   a. payback period
   b. capitalization
   c. discount rate
   d. market value

10. Over __________ of the capital invested by electric utilities in the United States is invested in massive networks of transmission and distribution equipment:

   a. 25 percent
   b. 33 percent
   c. 50 percent
   d. 66 percent

11. Secondary financial institutions do not include which of the following __________:

   a. Private Mortgage Insurance Companies
   b. Federal Housing Administration
   c. Government National Mortgage Association
   d. Federal National Mortgage Association

12. The use of __________ to insure solar access avoids the expense of public acquisition, places the responsibility of action only on interested individuals, and makes more permanent insurance than zoning laws:

    a. express easements
    b. implied easements
    c. eminent domain
    d. nuisance laws

13. A __________ building code establishes building construction requirements by reference to particular materials and methods:

    a. specification type
    b. performance type
    c. model
    d. local

14. __________ contract is one in the making of which the promisor has completely set forth his promise and has left nothing to inference:

    a. A simple
    b. An express
    c. A formal
    d. An implied

15. The solar industry is currently marketing solar equipment to the __________ consumer group:

    a. innovator
    b. early adopter
    c. early majority
    d. late majority

16. The method of economic evaluation of an investment whose principal benefits occur in the form of cost savings is __________:

    a. break-even cost
    b. simple payback
    c. discounted payback
    d. life-cycle costing

17. The most common electric rate structure is the __________:

    a. peak demand
    b. lifeline
    c. time-of-day
    d. declining block

18. Lenders appear to have _________ on the future of residential solar energy systems as an option for the average homeowner:

    a. a positive outlook
    b. a negative outlook
    c. no opinion
    d. no interest

19. _________ could be used to hinder solar homes as well as encourage them, since they are used to create private architectural review committees with authority to reject changes in building appearance:

    a. Planned unit developments
    b. Restrictive covenants
    c. Express easements
    d. Implied easements

20. Warranties of merchantability and fitness for a particular purpose are _________:

    a. express warranties
    b. implied warranties
    c. limited warranties
    d. full warranties

CODES, LEGALITIES, CONSUMERISM AND ECONOMICS

ANSWERS TO PRE-TEST

1. b. major cost reduction programs
2. d. internal rate of return
3. b. lifeline
4. b. HUD Intermediate Property Standards For Solar Systems
5. a. direct labor costs
6. b. subsidy
7. d. all of the above
8. d. a properly sized
9. c. discount rate
10. c. 50 percent
11. b. Federal Housing Administration
12. a. express easements
13. a. specification type
14. b. An express
15. b. early adopter
16. d. life-cycle costing
17. d. declining block
18. a. a positive outlook
19. b. restrictive covenants
20. b. implied warranties

CONSUMERISM

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Analysis indicates that __________ percent of the U. S. energy is consumed in industry and agriculture at temperatures below the boiling point of water:

   a. 1 to 4
   b. 2 to 7
   c. 5 to 10
   d. 10 to 15

2. To improve solar consumerism, the solar industry must devise and implement __________:

   a. new product lines
   b. major cost reduction programs
   c. innovative sales techniques
   d. simpler control devices

3. The solar industry is currently developing in a __________ and __________ manner:

   a. rapid and erratic
   b. slow and sluggish
   c. normal and healthy
   d. unusual and diverse

4. Financing a solar system __________:

   a. has not yet become a problem
   b. is a major problem
   c. involves time consuming activities
   d. requires a large down payment

5. Training in use of the ICBO "Solar Code Review Manual" would be appropriate for potential users to insure __________ and application:

   a. understanding
   b. uniformity of interpretation
   c. legal interpretation
   d. ordinance adoption

6. The benefits of solar equipment can only be realized if the prospective owners compare solar and alternative systems on the basis of __________ costs:

   a. fuel
   b. investment
   c. life-cycle
   d. operating

7. The solar industry needs training programs for dealers and contractors in areas of __________ and __________:

   a. financing and taxes
   b. technical and installation areas
   c. HVAC and plumbing
   d. sales and business management

8. Proper __________ and __________ of solar installers is a high priority action on the part of states:

   a. teaching and training
   b. testing and certification
   c. organization and direction
   d. identification and certification

9. An attractive financing plan for the mass market would have to generate __________ by the end of the first year:

   a. considerable interest
   b. a positive cash flow
   c. very low interest rates
   d. a sizable asset

10. A consensus within the solar industry has not been reached on what constitutes __________ solar system:

   a. an ideal
   b. an adequate
   c. an aesthetically appealing
   d. a properly sized

11. Solar will evolve into a widespread, beneficial industry if there is a supply of __________:

   a. good buyers
   b. reliable sunshine
   c. solar collectors
   d. solar products

12. The solar industry is currently marketing solar equipment to the __________ consumer group:

    a. innovator
    b. early adopter
    c. early majority
    d. late majority

13. For the most part, there is __________ between utilities and the solar DHW industry:

    a. conflict
    b. cooperation
    c. good communication
    d. a general lack of communication

14. Specific solar system and component assurance must be provided through the development of appropriate __________ programs:

    a. warranty
    b. government support
    c. demonstration
    d. codes, standards, and certification

15. Solar heating systems require __________ than conventional systems:

    a. higher maintenance costs
    b. higher capital costs
    c. higher operating costs
    d. all of the above

16. Solar consumers are __________ that solar domestic hot water is a "here and now" technology:

    a. aware
    b. not concerned
    c. convinced
    d. unaware

17. Most solar firms today are still __________ and __________:

    a. small and undercapitalized
    b. growing and healthy
    c. weak and unhealthy
    d. inexperienced and small

18. The solar industry is young and its customers and sales prospects need the reassurance which can be provided by __________:

    a. builders
    b. bankers
    c. utilities
    d. realtors

19. Proposed __________ has caused confusion within the solar industry and local government enforcement agencies:

    a. codes development
    b. zoning regulations
    c. government subsidies
    d. tax incentives

20. One simple economic method is __________, which involves a comparison of unit thermal energy costs delivered by the solar system and a conventional system:

    a. break-even analysis
    b. operating cost analysis
    c. life-cycle cost analysis
    d. supply and demand analysis

CONSUMERISM

ANSWERS TO POST-TEST

1. b. 2 to 7
2. b. major cost reduction programs
3. c. normal and healthy
4. a. has not yet become a problem
5. b. uniformity of interpretation
6. c. life-cycle
7. d. sales and business management
8. b. testing and certification
9. b. a positive cash flow
10. d. a properly sized
11. a. good buyers
12. b. early adopters
13. d. a general lack of communication
14. d. codes, standards, and certification
15. b. higher capital costs
16. d. unaware
17. a. small and undercapitalized
18. c. utilities
19. a. codes development
20. a. break-even analysis

ECONOMICS

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. The investment in solar energy is economically feasible if the __________ of energy savings over the lifetime of the investment exceeds the initial cash outlay:

   a. value
   b. present worth
   c. total
   d. percentage

2. The interaction of supply and demand forms the basis for __________, which can be used to compare and choose energy systems:

   a. costs
   b. discounting
   c. market value
   d. capitalization

3. __________ refers to the use of interest formulas to convert cash flows occurring at different times to equivalent amounts at a common point in time:

   a. Discounting
   b. Market value
   c. Capitalization
   d. Elasticity

4. Property taxes tend to increase the homeowner's cost for a solar system relative to a counterpart conventional system because of the greater __________ of the solar system:

   a. capital-intensiveness
   b. market value
   c. cost
   d. economic life

5. The __________ method of economic evaluation finds the interest rate for which lifetime dollar savings are just equal to the lifetime dollar costs:

   a. life-cycle cost
   b. net benefits
   c. benefit/cost
   d. internal rate of return

6. An energy system is said to be __________ when it achieves its purpose with the least misallocation of resources:

   a. discounted
   b. capitalized
   c. technically efficient
   d. economically efficient

7. Conceptually, __________ indicates how readily market decisions can adjust to price changes:

   a. opportunity costs
   b. marginal costs
   c. market value
   d. elasticity

8. A __________ stipulates a minimum rate of return which must be recovered on an investment over and above other investment costs:

   a. payback period
   b. capitalization
   c. discount rate
   d. market value

9. The __________ evaluation method measures the elapsed time between the point of an initial investment and the point at which accumulated savings are sufficient to offset the initial investment:

   a. payback
   b. break-even
   c. life-cycle cost
   d. net benefits

10. The __________ method of economic evaluation expresses savings from solar energy as a numerical ratio to investment costs:

    a. life-cycle cost
    b. net benefits
    c. benefit/cost
    d. internal rate of return

11. The cost of a resource is the price it would command [illegible] its best alternative use - its __________:

    a. market value
    b. discounted value
    c. opportunity cost
    d. marginal cost

12. Market equilibrium can be altered by changes in __________ and __________ decisions:

    a. sales and installation
    b. production and consumption
    c. capitalization and financing
    d. opportunity costs and investment

13. The __________ of an asset is that period during which the asset is expected to be retained in use for its intended purpose at the minimum cost for achieving that purpose:

    a. payback period
    b. life-cycle
    c. capitalization
    d. economic life

14. The method of economic evaluation of an investment whose principal benefits occur in the form of cost savings is __________:

    a. break-even cost
    b. simple payback
    c. discounted payback
    d. life-cycle costing

15. The __________ method of economic evaluation finds the difference between the lifetime dollar energy savings from an investment in solar energy and its lifetime dollar costs:

    a. life-cycle cost
    b. net benefits
    c. benefit cost
    d. internal rate of return

16. The extra costs that will be incurred by a decision are known as __________:

    a. marginal costs
    b. opportunity costs
    c. operating costs
    d. life-cycle costs

17. A necessary step in any comprehensive economic evaluation method is the adjustment of the various cost items to __________:

    a. equivalent time base
    b. equivalent dollar base
    c. economic life base
    d. opportunity cost base

18. By dividing all system costs into __________ and __________ components, the cost-estimating process for solar systems can be simplified:

    a. maintenance and operating
    b. collection and distribution
    c. fixed and variable
    d. exterior and interior

19. The __________ method of economic evaluation means the summing of acquisition, maintenance, repair, replacement, and energy costs over the life of the investment:

    a. life-cycle cost
    b. net benefits
    c. benefit/cost
    d. internal rate of return

20. The life-cycle cost method is __________ effective for evaluating investments in solar energy relative to competing investments:

    a. always
    b. not always
    c. especially
    d. never

ECONOMICS

ANSWERS TO POST-TEST

1. b. present worth
2. c. market value
3. a. Discounting
4. a. capital intensiveness
5. d. internal rate of return
6. d. economically efficient
7. d. elasticity
8. c. discount rate
9. a. payback
10. c. benefit/cost
11. c. opportunity cost
12. b. production and consumption
13. d. economic life
14. d. life-cycle costing
15. b. net benefits
16. b. net benefits
17. a. an equivalent time base
18. c. fixed and variable
19. a. life-cycle cost
20. b. not always

UTILITY INTERFACING

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Public utility is a business directly connected with public __________ and __________:

    a. service and administration
    b. supply and demand
    c. health and welfare
    d. regulation and control

2. The advantages of interconnecting centralized and onsite systems is magnified by the fact that most generating devices operate __________ when operated to meet an uneven demand:

    a. continuously
    b. intermittently
    c. more efficiently
    d. less efficiently

3. The performance of isolated and interconnected energy systems can be __________ if utility control is exercised over devices which consume energy as well as over energy storage and generating equipment:

    a. improved
    b. impeded
    c. effective
    d. ineffective

4. The __________ may benefit solar users whose needs for supplemental sources of energy fall within qualifying amounts:

    a. peak demand rate
    b. lifeline rate
    c. time-of-day rate
    d. interruptible rate

5. One of the major purposes for __________ of electric utilities is the prevention of unreasonable discrimination or undue preferences:

    a. public regulation
    b. rate structures
    c. public ownership
    d. private ownership

6. Over __________ of the electrical generating capacity in the United States is the property of private power companies:

   a. 30 percent
   b. 50 percent
   c. 65 percent
   d. 75 percent

7. There should be __________ in constructing equipment capable of providing power to utilities which meets utility standards of voltage regulation and frequency control from onsite solar systems:

   a. considerable difficulty
   b. no difficulty
   c. specialized training
   d. minimal training

8. Over __________ of the capital invested by electric utilities in the United States is invested in massive networks of transmission and distribution equipment:

   a. 25 percent
   b. 33 percent
   c. 50 percent
   d. 66 percent

9. A solar user willing to accept the risk of going without utility service on infrequent occasions may qualify for __________:

   a. peak demand rates
   b. lifeline rates
   c. time-of-day rates
   d. interruptible rates

10. Through use of regulations, the Public Utilities Regulatory Policies Act requires that utility rate structures reflect __________ of providing service to each class of consumer:

    a. generating costs
    b. distribution costs
    c. true cost
    d. fuel costs

11. From the standpoint of solar energy use, the crucial regulatory function is __________:

    a. rate approval
    b. service criteria
    c. utility ownership of systems
    d. utility purchase of excess onsite energy

12. Onsite industrial cogeneration has been __________ by long-standing policies on the part of most privately owned electric utilities:

a. discouraged
b. encouraged
c. implemented
d. prohibited

13. The most common residential electric rate structure is the __________:

a. peak demand
b. lifeline
c. time-of-day
d. declining block

14. There are __________ for sale of surplus power to utility companies:

a. numerous arrangements
b. few arrangements
c. local arrangements
d. national arrangements

15. Under most state statutes a __________ is defined to include any person, corporation, partnership, association, or other legal entity and their various representatives:

a. municipal utility
b. public utility
c. private utility
d. all of the above

16. Widespread use of onsite solar equipment would reverse a __________ trend toward centralization of energy sources:

a. 40-year
b. 30-year
c. 20-year
d. 10-year

17. If the solar equipment is installed in a significant fraction of a building served by a utility, the load pattern which the utility must meet could __________:

a. be a peak demand
b. be essentially unaltered
c. be significantly affected
d. be of no concern to the utility

18. Larger utility customers are frequently charged on the basis of their __________ during some specified period:

    a. peak demand use
    b. lifeline use
    c. time-of-day use
    d. declining block use

19. Current laws __________ discriminatory rates for solar customers under certain conditions:

    a. will not permit
    b. intentionally provide
    c. will permit
    d. do not consider

20. It is __________ that an existing public utility will be permitted to own a solar system which is permanently placed on the roof or other property of a customer:

    a. clear
    b. unclear
    c. mandatory
    d. not reasonable

UTILITY INTERFACING

ANSWERS TO POST-TEST

1. c. health and welfare
2. d. less efficiently
3. a. improved
4. b. lifeline
5. a. public regulation
6. d. 75 percent
7. b. no difficulty
8. b. 50 percent
9. d. interruptible rates
10. c. true cost
11. a. rate approval
12. a. discouraged
13. d. declining block
14. b. few arrangements
15. b. public utility
16. a. 40-year
17. c. be significantly affected
18. a. peak demand use
19. c. will permit
20. b. unclear

FINANCIAL ISSUES

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. The large amount of capital __________ solar systems in relation to the __________ keeps ownership out of reach for most buyers unless credit aid is available:
   a. required for -- conventional systems
   b. down payment for -- total cost
   c. necessary to finance -- small annual income
   d. required for -- funding available

2. The condition of surrounding property and the trend of an area can __________ a given property:

   a. adversely affect
   b. undervalue
   c. overvalue
   d. have little effect on

3. The Federal Housing Administration was established to __________ conventional mortgage loans:

   a. make
   b. guarantee
   c. insure
   d. promote

4. FHA officials do not want to do disservice to homebuyers by appraising solar systems at full cost where __________ is or may be less than solar system cost:

   a. energy saving
   b. auxiliary energy
   c. market value
   d. none of the above

5. A __________, by economic definition, means government action which provides income given to a person or group to support and encourage activities that are deemed beneficial to the public:

   a. grant
   b. subsidy
   c. tax credit
   d. low-interest loan

6. A solar energy system will have an impact on the owner's __________:

   a. cash flow
   b. life style
   c. financial interest
   d. financing terms

7. Although the cost of a residential solar energy system may be large or small, the borrower's choices for financing are limited by __________:

   a. the residential purpose for the loan
   b. the lender's attitude
   c. funds available
   d. government regulations

8. Secondary financial institutions do not include which of the following:

   a. Private Mortgage Insurance Companies
   b. Federal Housing Administration
   c. Government National Mortgage Association
   d. Federal National Mortgage Association

9. The secondary market entities, FNMA and FHLMC, perceive their basic public function as necessitating __________ toward underwriting the risks associated with unproven housing technologies:

   a. no interest
   b. a great deal of interest
   c. a conservative stance
   d. a liberal stance

10. There may be general legal problems with exempting solar equipment from property tax assessments, since the majority of states have __________ in their constitutions and/or tax laws:

    a. limitations
    b. no provisions
    c. ambiguity
    d. uniformity clauses

11. There are three basic ways of obtaining funds for residential purposes __________, __________, and __________:

    a. conventional loans, FHA loans, and second mortgage loans
    b. VA loans, conventional loans, and FHA loans
    c. second mortgage loans, conventional loans, and Title I loans
    d. home improvement loans, second mortgage loans, and first mortgage loans

12. Credit unions, finance companies, and retail credit plans are sources for __________:

    a. first mortgage loans
    b. second mortgage loans
    c. short-term loan financing
    d. long-term loan financing

13. Lenders appear to have __________ on the future of residential solar energy systems as an option for the average homeowner:

    a. a positive outlook
    b. a negative outlook
    c. no opinion
    d. no interest

14. As long as solar technology remains in the experimental stage, lenders will often be willing to make loans only when __________:

    a. their risk is reduced
    b. high interest rates are imposed
    c. a large down payment is made
    d. a short payback period is used

15. The Solar Bank is a mechanism for delivering __________ in connection with borrowing to finance the purchase of solar energy equipment:

    a. A federal grant
    b. an insured provision
    c. a Federal subsidy payment
    d. a guaranteed provision

16. The lender uses borrower supplied information, such as financial means, borrower's occupation, income, assets, and financial obligations to __________:

    a. establish the interest rate
    b. qualify the borrower
    c. establish the loan principal
    d. establish the loan period

17. Mortgage loan financing markets are classified as __________ and __________:

    a. individual lenders and institutional lenders
    b. primary markets and secondary markets
    c. government agencies and private agencies
    d. short-term lenders and long-term lenders

18. Whatever lenders attitudes on public issues may be, they must __________ in a manner that accords with their day to day standards of business operations:

    a. set interest rates
    b. establish payback periods
    c. require down payments
    d. make loan decisions

19. One of the attractive features of onsite solar equipment is that it may be the only new energy source that can be __________ without Federal assistance of any kind:

    a. marketed
    b. regulated
    c. subsidized
    d. developed, financed, and installed

20. Application of mandatory ordinances to specific buildings may be held invalid where the property owner can demonstrate that __________:

    a. costs clearly exceed benefits
    b. ordinance is clearly discriminatory
    c. he was unaware of the ordinance
    d. all of the above

FINANCIAL ISSUES

ANSWERS TO POST-TEST

1. c. necessary to finance -- small annual income
2. a. adversely affect
3. c. insure
4. c. market value
5. b. subsidy
6. a. cash flow
7. a. the residential purpose for the loan
8. b. Federal Housing Administration
9. c. a conservative stance
10. d. uniformity clauses
11. d. home improvement loans, second mortgage loans, and first mortgage loans
12. c. short-term loan financing
13. a. a positive outlook
14. a. their risk is reduced
15. c. a Federal subsidy payment
16. b. qualify the borrower
17. b. primary markets and secondary markets
18. d. make loan decisions
19. d. developed, financed, and installed
20. a. costs clearly exceed benefits

LEGALITIES

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Onsite solar facilities are controlled by laws and regulations often written __________:

   a. to be intentionally restrictive
   b. with entirely different systems in mind
   c. by local officials
   d. by inexperienced individuals

2. A solar easement obligates the owner of the servient estate __________ to the dominant estate:

   a. to render compensation
   b. not to render compensation
   c. not to obstruct the sunlight passing over his estate
   d. to obstruct the sunlight passing over his estate

3. __________ can both facilitate and frustrate the collection of solar energy for heating and cooling purposes:

   a. Regional land planning
   b. Zoning law
   c. Building officials
   d. None of the above

4. By declaring the shading of solar equipment to be __________, jurisdictions could grant solar energy users protection similar to that offered by public acquisition of solar easements:

   a. public nuisance
   b. equivalent to water rights
   c. express easements
   d. implied easements

5. A large fraction of the value of solar equipment is attributable to __________:

   a. direct labor costs
   b. special materials costs
   c. complex fabrication procedures
   d. specialized control devices

6. The value interdependence of one land site or location on another has caused individuals directly, and groups collectively, through community action to __________ current land uses and future land use patterns:

    a. establish safeguards and control over
    b. disregard
    c. be aware of
    d. negotiate for

7. The use of __________ to insure solar access avoids the expense of public acquisition, places the responsibility of action only on interested individuals, and makes more permanent insurance than zoning laws:

    a. express easements
    b. implied easements
    c. eminent domain
    d. nuisance laws

8. __________ are flexible enough to incorporate any design objective, including solar access:

    a. Restrictive covenants
    b. Implied easements
    c. Transferable development rights
    d. Planned unit developments

9. Because solar energy is used, not extracted for sale, and because its availability is not diminished by use, __________ could be used to implement the novel concept of guaranteed solar access:

    a. transferable development rights
    b. oil and gas law
    c. nuisance law
    d. water rights law

10. Employment in installing solar energy equipment is likely to be __________ the building industry:

    a. as competitive as
    b. dominated by
    c. as geographically dispersed as
    d. restricted by

11. One of the negative environmental effects of solar energy devices stems primarily from __________:

    a. rooftop installations
    b. large storage systems
    c. glass for glazing
    d. land use requirements

12. Most legal authorities conclude that a grant of solar rights __________ would never pass judicial muster in the United States:

    a. under eminent domain
    b. water rights law
    c. restrictive covenants
    d. based purely on prescription

13. Under a __________ approach, owners of restricted property would be allowed to sell rights they could not use to owners of property zoned for more dense development:

    a. planned unit development
    b. zoning ordinance
    c. transferable development rights
    d. nuisance law

14. Insurance companies __________ to provide insurance for solar heated structures:

    a. have been reluctant
    b. have not been reluctant
    c. do not consider it necessary
    d. consider it necessary

15. Organized labor has occasionally resisted the introduction of new technologies into the building industry, but this resistance has always been directed at technologies which __________ or __________ from one building trade to another:

    a. change or discriminate
    b. reduce jobs or transfer employment
    c. favor or provide undue precedence
    d. all of the above

16. As a general rule, the owner of land in the United States has __________ to the light, air, and view from the adjoining land:

    a. legal rights
    b. implied rights
    c. no legal right
    d. no implied rights

17. __________ could be used to hinder solar homes as well as encourage them, since they are used to create private architectural review committees with authority to reject changes in building appearance:

    a. Planned unit developments
    b. Restrictive covenants
    c. Express easements
    d. Implied easements

18. Since large land developments will come under the __________ requirement in most states, this procedure might be used to assure consideration of solar energy utilization:

    a. land use planning
    b. energy impact statement
    c. regulatory
    d. all of the above

19. With regard to solar energy manpower, the concern is that __________ manpower could constrain the development and acceptance of solar energy as an alternative energy source:

    a. excessive
    b. specially trained
    c. highly organized
    d. a lack of adequately trained

20. There are __________ solar installer certification or contractor licensing procedures in force at this time:

    a. adequate
    b. not adequate
    c. complex
    d. unnecessary

LEGALITIES

ANSWERS TO POST-TEST

1. b. with entirely different energy systems in mind
2. c. not to obstruct the sunlight passing over his estate
3. b. zoning law
4. a. public nuisance
5. a. direct labor costs
6. a. establish safeguards and control over
7. a. express easements
8. d. Planned unit developments
9. a. water rights law
10. c. as geographically dispersed
11. d. land use requirements
12. d. based purely on prescription
13. c. transferable development rights
14. b. have not been reluctant
15. b. reduce jobs or transfer employment
16. c. no legal right
17. b. Restrictive covenants
18. b. energy impact statement
19. d. a lack of adequately trained
20. b. no adequate

BUILDING CODES, STANDARDS, WARRANTIES

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Building codes establish __________ to protect the health, safety and general welfare of the public:

   a. specific requirements
   b. no requirements
   c. minimum requirements
   d. inadequate requirements

2. Standards may be the work of a governmental agency or groups interested in establishing __________:

   a. special interests
   b. minimum levels of safety and performance
   c. research and development objectives
   d. regulatory controls

3. The __________ should be a useful reference source for local officials seeking to amend local building codes to accommodate solar energy systems:

   a. HUD Minimum Property Standards for Solar Systems
   b. Uniform Solar Energy Code
   c. Model Document For Code Officials
   d. Code Manual For Passive Solar Design

4. Insofar as applicable, the __________ applies to active and passive solar energy systems that utilize building elements, mechanical subsystems, or combinations thereof:

   a. Uniform Solar Energy Code
   b. HUD Intermediate Property Standards For Solar Systems
   c. Model Document For Code Officials
   d. Code Manual For Passive Solar Design

5. Today, a manufacturer or producer who makes inaccurate or misleading factual statements __________ is liable for resulting injuries to consumers:

   a. in implied warranties
   b. indiscriminately
   c. about certain products
   d. in advertising or labels

6. A __________ building code establishes building construction requirements by reference to particular materials and methods:

   a. specification type
   b. performance type
   c. model
   d. local

7. The principal hazards to health and safety from __________ are derived from the risk of leakage, fire, or explosion:

   a. building construction
   b. mechanical systems
   c. plumbing systems
   d. solar energy systems

8. Provisions of the Uniform Solar Energy Code are applicable to __________:

   a. installation and maintenance of electrical systems
   b. installation and maintenance of plumbing systems
   c. installation and maintenance of mechanical systems
   d. design and construction of passive systems

9. Warranties are __________ made by the seller or manufacturer assuring the purchaser of satisfaction in the use of the merchandise:

   a. contracts
   b. covenants
   c. statement of promises
   d. agreements

10. An advertiser of solar product test results must have in his possession, prior to the time a claim is made, __________ for any such claim:

   a. a reasonable basis
   b. certified test results
   c. calculated test information
   d. test procedures to be used

11. A __________ building code establishes design and engineering criteria without reference to specific methods of construction:

   a. specification type
   b. performance type
   c. model
   d. local

12. The __________ may be the most important building code problem for solar systems:

    a. attitude of building officials
    b. local zoning ordinance
    c. lack of standards
    d. specification type building code

13. The __________ program for solar collectors is viewed as a possible mechanism for accrediting laboratories that test solar equipment:

    a. National Voluntary Accreditation
    b. HUD Minimum Property Standards For Solar
    c. ASHRAE Standards
    d. NBS Interim Performance Criteria

14. Any affirmation of fact or any promise by the seller relating to goods is an __________:

    a. express warranty
    b. implied warranty
    c. limited warranty
    d. full warranty

15. The HUD Minimum Property Standards __________ construed as relieving the builder of his responsibility for compliance with local ordinances, codes and regulations:

    a. will be
    b. shall not be
    c. can be
    d. should not be

16. A __________ building code, developed by industry, professional groups, and states, may be adopted into law for use in local communities:

    a. specification type
    b. performance type
    c. model
    d. local

17. The ideal solution to potential building code problems for solar systems would be __________ and __________ for the various kinds of solar energy systems:

    a. nationally recognized standards and testing procedures
    b. standardization and sizing
    c. licensing and certification
    d. all of the above

18. The HUD Minimum Property Standards are intended to provide __________ for the planning and design of housing:

    a. guidelines
    b. legal basis
    c. acceptable test methods
    d. a sound technical basis

19. Warranties of merchantability and fitness for a particular purpose are __________:

    a. express warranties
    b. implied warranties
    c. limited warranties
    d. full warranties

20. There appears to be _________ as to thermal efficiency or heat delivery capacity of solar equipment:

    a. adequate manufacturer's guaranty
    b. no manufacturer's guaranty
    c. limited manufacturer's guaranty
    d. full manufacturer's guaranty

BUILDING CODES, STANDARDS, WARRANTIES

ANSWERS TO POST-TEST

1. c. minimum requirements
2. b. minimum levels of safety and performance
3. c. Model Document For Code Officials
4. b. HUD Minimum Property Standards For Solar Systems
5. d. in advertising or labels
6. a. specification type
7. d. solar energy systems
8. b. installation and maintenance of plumbing systems
9. c. statement of promises
10. a. a reasonable basis
11. b. performance type
12. c. lack of standards
13. a. National Voluntary Accreditation
14. a. express warranty
15. b. shall not be
16. c. model
17. a. nationally recognized standards and testing procedures
18. d. a sound technical basis
19. b. implied warranties
20. b. no manufacturer's guaranty

THE CONTRACTING SYSTEM

POST-TEST

Directions: Circle the answer or answers you believe to be correct.

1. Which of the following are necessary for consumer protection in dealing with contractors __________:

    a. check the contractor out
    b. make the contractor bid competitively
    c. don't overpay the contractor during construction
    d. all of the above

2. Be sure, if you have been dealing with a representative of the contractor, that __________ is on the contract:

    a. the name of the contractor
    b. the name of the representative
    c. both a and b
    d. your name

3. In the proposal preparation, items that should be included in __________ are: health and life insurance, paid vacations, holiday and sickness allowances, and bonus and pension plans:

    a. employee benefits package
    b. education costs
    c. insurance and taxes
    d. overhead and miscellaneous expenses

4. __________ include contracts of record, contracts under seal, and negotiable instruments:

    a. Simple contracts
    b. Express contracts
    c. Formal contracts
    d. Implied contracts

5. The __________ may be defined as a security claim given by statute to those who perform labor or furnish material in the improvement of real property:

    a. mechanic's lien
    b. attachment
    c. judgment
    d. vendor's lien

6. One thing to consider when buying a solar system not sold as a single package by one manufacturer, is to obtain assurance that the seller has had __________:

   a. special training from each manufacturer involved
   b. professional experience of choosing properly
   c. a past history of success
   d. no charges of misrepresentation

7. In preparing proposals, the costs and profits are best calculated __________ material is used or labor performed:

   a. according to what
   b. without regard to what
   c. in a manner to show how
   d. in the sequence in which

8. To be certain that you do not underprice proposal items, you should know __________ for the total of all items to cover expenses and profits:

   a. basic costs
   b. actual costs
   c. the percentage of gross margin to sales needed
   d. the markup necessary

9. __________ contract is one in the making of which the promisor has completely set forth his promise and has left nothing to inference:

   a. a simple
   b. an express
   c. a formal
   d. an implied

10. The __________ is a statutory privilege given to a plaintiff or complainant in the courts in an action for money damages before any judgment is procured:

    a. mechanic's lien
    b. attachment
    c. vender's lien
    d. vendor's lien

11. Don't ask, or allow, anyone to bid on your construction project unless he is __________:

    a. someone to whom you would be willing to award the job
    b. a licensed contractor
    c. one you have thoroughly checked out
    d. an established contractor

12. In the proposal preparation, include the cost of __________ subcontractor's work, if you are responsible for such work:

    a. negotiating for
    b. supervising and inspecting
    c. each
    d. appropriate

13. A contract in its most important aspect is a device by which persons make __________ for the future:

    a. promises
    b. binding arrangements
    c. commitments
    d. verbal agreements

14. In doubtful cases, where the parties of a contract have not made their intent clear, the courts are inclined to say that a given promise is __________:

    a. unilateral
    b. bilateral
    c. voidable
    d. unenforceable

15. Judgments for the payment of money, when properly docketed, become __________ on all property of the debtor:

    a. mechanic's liens
    b. vender's liens
    c. general liens
    d. vendor's liens

16. Be sure that your agreement with a contractor has __________ freeing you from liability if the contractor goes bankrupt before the job is finished:

    a. means for
    b. been negotiated
    c. written provision
    d. verbal arrangements

17. In the proposal preparation, items that should be included in __________ are: workmen's compensation, FICA (employer's share), unemployment taxes (federal and state), union dues, and inspection fees:

    a. employee benefits package
    b. education costs
    c. insurance and taxes
    d. overhead and miscellaneous expenses

18. Which of the following is not an essential of a valid contract __________:

    a. an agreement — both offer and acceptance
    b. a limited warranty
    c. a consideration
    d. parties having capacity to contract

19. A __________ is the right given by law to a creditor to have a debt or charge satisfied out of the property belonging to the debtor:

    a. contract
    b. promise
    c. lien
    d. bond

20. The usual rule as to priority of liens is that they rank in the __________:

    a. order of their filing
    b. order of their importance
    c. order of their value
    d. order of the date signed

THE CONTRACTING SYSTEM

ANSWERS TO POST-TEST

1. d. all of the above
2. a. the name of the contractor
3. a. employee benefits package
4. c. formal contracts
5. a. mechanic's lien
6. b. professional experience of choosing properly
7. d. in the sequence in which
8. c. the percentage of gross margin to sales needed
9. b. an express
10. b. attachment
11. a. someone to whom you would be willing to award the job
12. b. supervising and inspecting
13. b. binding arrangements
14. b. bilateral
15. c. general liens
16. a. written provision
17. c. insurance and taxes
18. b. a limited warranty
19. c. lien
20. a. order of their filing

NON-RESIDENTIAL APPLICATIONS AND FUTURE TECHNOLOGY

Semester Hours Credit: 3
Lecture: 2
Lab: 3

Project Direct: Charles G. Orsak, Jr.

Prime Author: Bob Takacs

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INTRODUCTION:

The Non-Residential Applications and Future Technology course presents solar energy use for agricultural, commercial, and industrial applications. Principles of operation and the design of simple systems are described for each of the applications. The depth of coverage and extent of details must be left to the discretion of the instructor. Printed materials will be handed out to the students on selected subjects, leaving more time for classroom/laboratory instruction in needed areas. There is the possibility that many programs will not have appropriate lab facilities for this course, i.e., agricultural, commercial, industrial.

COURSE DESCRIPTION:

This course presents non-residential solar energy applications and systems. Specific uses include agricultural, commercial, and industrial sector applications. The loads, temperature requirements, and solar system design are related to various applications in each of the sectors. Laboratory lessons are used to develop the student's skill in designing systems related to the different sector's solar applications. Additionally, possibilities in future solar technology are presented. Both future developments in existing equipment and the development of new systems are discussed.

COURSE PREREQUISITES:

System Sizing, Design and Retrofit.

COURSE OBJECTIVES:

Upon completion of this course, the student should be able to:

(1) Discuss appropriate solar systems for specific agricultural, commercial, and industrial applications.

(2) Discuss appropriate solar systems for specific temperature requirements.

(3) Evaluate and discuss possible advantages of using solar equipment and systems for specific agricultural, commercial, and industrial applications.

(4) Describe the possible advances to be made in solar equipment and systems.

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MODULE: AGRICULTURAL, COMMERCIAL AND INDUSTRIAL POWER DEMANDS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe the various energy resources and energy conversion devices used for agricultural, commercial, and industrial applications from the 16th century to the present.

(2) Classify solar energy applications according to temperature ranges of the solar supplied thermal energy.

(3) Explain the dependence of solar collector efficiency on collector temperature.

RATIONALE:

In order for the student to grasp the importance of energy demand outside the residential sector, he/she must understand the various energy resources and energy conversion devices used for the agricultural, commercial, and industrial sectors as well. This module explores these applications from the 16th century to the present and classifies solar energy applications according to temperature ranges of the solar supplied thermal energy.

REFERENCES:

(1) Meinel and Meinel, Applied Solar Energy, Addison-Wesley, 1976.

(2) Daniels, Yale, Direct Use of the Sun's Energy, 1964.

(3) Kreider and Kreith, Solar Heating and Cooling, revised first edition, Hemisphere, 1977.

(4) Metz and Hammond, Solar Energy in America, AAAS, 1978.

(5) Solar Energy Handbook - Theory And Applications, Power Systems Group, Ametak, Inc., 1979.

UNIT TITLES:

(1) Brief History of Energy Use

(2) Thermal Energy Classification by Temperature Range

MODULE: AGRICULTURAL, COMMERCIAL AND INDUSTRIAL POWER DEMANDS

VOCABULARY:

Agricultural
Commercial
Industrial
Energy
Power
Thermal Energy
Mechanical Energy
Electrical Energy
Electricity
Energy Conversion
Solar Energy
Engine
Motor
Generator
Central Power Plant
Transmission
Energy Resource
Fossil Fuel
Temperature
Insolation
Solar Collector
Glazing
Collector Efficiency
Flat Plate Collector
Concentrating Collector
Tracking Collector
Reflector
Parabolic Reflector
Fresnel Lens
Evacuated Tube

Reference 1, Chap. 1
2, Chap. 2
3, Chap. 1

Unit 1. Brief History of Energy Use

A. Agricultural and Industrial developments since 1600
B. Displacement of manpower with machine power
C. Development of electricity and central power plants
D. U.S. energy resource consumption patterns and end-use patterns

Reference 2, Chap. 4
3, Chap. 3
4, Chap. 5
5, Chap. 5

Unit 2. Thermal Energy Classification by Temperature Range

A. Definitions of temperature range classifications (low, medium, high)
B. Typical applications for thermal energy in each temperature range
C. Solar collector designs with applicability in each temperature range

INSTRUCTOR ACTIVITIES:

Laboratory:

Inspect laboratory equipment to determine if the collector test procedure described in Reference 3, App A, can be followed. If not, modify the instructions as appropriate for the equipment on hand.

STUDENT ACTIVITIES:

Laboratory:

Lab Exercise:

Prepare collector test system as described in the reference, or by the instructor.

Reference 3, App A

Perform brief collector efficiency tests for a flat plate and concentrating collector, each with a low temperature and a medium temperature load.

Laboratory Materials:

(1) Flat plate collector
(2) Concentrating collector
(3) Auxiliary heater
(4) Collector test stand or other mounting hardware
(5) Temperature gauges, flowmeters, and recording equipment as required

MODULE: AGRICULTURAL APPLICATIONS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe and generally design solar systems for various specific agricultural applications.

(2) Describe the market potential for solar systems in the agricultural sector.

RATIONALE:

Solar can play an important role in an agricultural setting. The solar technician must be aware of the potential applications for solar energy in this area. This module acquaints the solar student with solar uses in livestock shelters, crop drying, greenhouses, distillation, and irrigation.

REFERENCES:

(1) Davis and Schubert, *Alternate Natural Energy Sources in Building Design*, Van Nostrand Reinhold, 1977.

(2) *Energy for Rural Development*, National Academy of Sciences, 1976.

(3) *Solar Energy Handbook - Theory and Applications*, Power Systems Group, Ametek, Inc., 1979.

(4) Daniels, Yale, *Direct Use of the Sun's Energy*, 1964.

(5) Kreider and Kreith, *Solar Heating and Cooling*, revised first edition, Hemisphere, 1977.

(6) *Solar Crop Drying Conference*, *Proceedings*, Weaver Laboratories, North Carolina State University at Raleigh, June 30, 1977.

(7) *Third Annual Conference on Solar Energy for Heating of Green Houses and Greenhouse-Residence Combinations*, *Proceedings*, Colorado State University, Solar Energy Applications Laboratory, April 2-5, 1978.

(8) Beckman & Duffie, *Solar Energy Thermal Processes*, Wiley, 1974.

(9) Meinel and Meinel, *Applied Solar Energy*, Addison-Wesley, 1976.

UNIT TITLES:

(1) Livestock Shelters
(2) Crop Drying
(3) Greenhouses
(4) Distillation
(5) Irrigation

VOCABULARY:

Space Heating
Temperature
Thermal Energy
Solar Energy
Insolation
Insulation
Passive Solar System
Active Solar System
Air System
Liquid System
Water Heating
Domestic Water Heating
Photovoltaics
Glazing
Drying
Distillation
Still
Potable
Single Effect
Double Effect
Hybrid
Mechanical Energy
Pump
Engine
Heat Engine
Wind Generators

Reference 1, Chap. 4 2 3, Chap. 6 5, Chap. 4	Unit 1. Livestock Shelters A. Uses of thermal energy for agricultural purposes by: 1. End-use application 2. Types of fuel used 3. Temperature range
Handout showing pictures and specifications of solar heated livestock shelters	B. Potential for solar energy systems in agriculture by: 1. Temperature range 2. Conventional fuel economics C. Description of livestock shelters and heating temperatures required D. Passive and active solar heating systems that meet livestock shelter heating requirements
Reference 6	Unit 2. Crop Drying A. Load requirements for drying various types of crops - fruits, vegetables, nuts, grains, tobacco and lumber
Handout of pictures and specifications of solar crop drying systems	B. Temperature requirements for A above
Reference 7 Handout of pictures and specifications of solar heated greenhouses	Unit 3. Greenhouses A. Description of greenhouses for agricultural and commercial applications, including thermal energy load and temperature requirements B. Description and design of passive and active solar greenhouse systems
Reference 2 4, Chap. 10 8, Chap. 15	Unit 4. Distillation A. Applications of distillation systems B. Principles of operation of single effect distillation systems C. Temperature, energy, and water requirements of distillation systems D. Design of solar distillation systems

Reference 9, Chap. 16

Unit 5. Irrigation

A. Components of irrigation systems: source, distribution, pumping
B. Photovoltaic collection and conversion for water pumping
C. Wind powered pumping
D. Solar driven heat engines for water pumping

INSTRUCTOR ACTIVITY

Laboratory:

Specify a type and population of an animal shelter to be solar heated.

STUDENT ACTIVITY

Laboratory:

Exercise I

Design an active solar heating system for a livestock shelter.

Laboratory Materials:

Drawing board and related drafting equipment.

INSTRUCTOR ACTIVITY

Laboratory:

Specify a grain type and associated drying load for a solar drying system.

STUDENT ACTIVITY

Laboratory:

Exercise II

Design a forced-air solar grain drying system.

Laboratory Materials:

Drawing board and related drafting equipment.

INSTRUCTOR ACTIVITY

Laboratory:

Specify size and load of model greenhouse.

STUDENT ACTIVITY

Laboratory:

Exercise III

Design and construct model solar greenhouse with thermal energy storage.

Laboratory Materials:

1. Drawing board and associated drafting equipment.
2. Clear and opaque plastic.
3. 2 x 4's for structure framing.
4. Carpentry tools: hammer, nails, saw.
5. Thermal energy storage media (gravel or water).

INSTRUCTOR ACTIVITY

Laboratory:

Specify production requirements for a model solar still.

STUDENT ACTIVITY

Exercise IV

Laboratory:

Design, construct, and operate a small solar distillation system.

Laboratory Materials:

1. Drawing board and associated drafting equipment.
2. Clear and opaque plastic.
3. 2 x 4's for structure framing.
4. Carpentry tools: hammer, nails, saw.
5. Thermal energy storage media (gravel or water).

INSTRUCTOR ACTIVITY

Laboratory:

Specify an average daily volume requirement for a solar-powered irrigation system.

STUDENT ACTIVITY

Assignment:

Laboratory:

Size a wind-generator system for delivering the specified average daily volume of water.

MODULE: COMMERCIAL APPLICATIONS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe and generally design solar systems for various commercial applications.

(2) Generally assess the potential for solar energy impact in the commercial market.

RATIONALE:

Solar in the commercial market is making an ever increasing impact. The purpose of this module is to make the student aware of the various commercial applications of solar energy in such businesses as laundries, restaurants, and car washes.

REFERENCES:

(1) Duffie and Beckman, Solar Energy Thermal Processes, Wiley, 1974.

(2) Kreider and Kreith, Solar Heating and Cooling, revised first edition, Hemisphere, 1977.

(3) Solar Energy Handbook - Theory and Applications, Power Systems Group, Ametek, Inc., 1979.

UNIT TITLES:

(1) Livestock Shelters

(2) Crop Drying

VOCABULARY:

Thermal Energy
Solar Energy
Fossil Fuel
Energy Resource
Temperature
Space Heating
Domestic Water Heating
Process Hot Water
Space Cooling
Solar Collector
Insolation
Insulation
Collector Efficiency
Air System
Liquid System
Flatplate Collector
Concentrating Collector
Tracking Collector
Evacuated Tube
Reflector

Reference 1, Chap. 11
2, Chap. 4
3, Chap. 6,7

Unit 1. General Applications

- A. Commercial thermal energy applications by:
  - 1. End-use (hot water, steam, space heating, space cooling)
  - 2. Fuel type (oil, gas, coal, electricity)
  - 3. Temperature range
- B. Potential for solar energy system for commercial purposes by:
  - 1. Temperature range of load
  - 2. Conventional fuel economics
  - 3. Solar usage projections
- C. Description of thermal energy loads for commercial buildings
- D. Commercial processes requiring low - and intermediate - temperature thermal energy

Reference 1, 2, 3

Unit 2. Specific Applications Solar System Layout and Design for Thermal Energy Requirements in:

- A. Laundries
  - 1. Space heating
  - 2. Process (washer) hot water
  - 3. Process hot air
- B. Restaurants
  - 1. Space heating
  - 2. Domestic hot water
  - 3. Dishwashing hot water
- C. Car washes
  - 1. Space heating
  - 2. Washer hot water
  - 3. Dryer hot air

INSTRUCTOR ACTIVITY

Laboratory:

Specify the various thermal energy loads for a laundry.

STUDENT ACTIVITY

Exercise I

Laboratory:

Design a collector array for meeting the specified loads of a laundry.

Laboratory Materials: Drawing board and related drafting equipment.

INSTRUCTOR ACTIVITY	Laboratory: Specify the various thermal energy loads for a restaurant.
STUDENT ACTIVITY	Laboratory:
Exercise II	Design a solar system with storage for meeting a specified load for a restaurant.
Laboratory Materials:	Drawing board and related drafting equipment.
INSTRUCTOR ACTIVITY	Laboratory: Specify the various thermal energy loads and washing schedule for a car wash.
STUDENT ACTIVITY	Laboratory:
Exercise III	Design a collector array and storage system for meeting a specified car washing schedule.
Laboratory Materials:	Drawing board and related drafting equipment.

MODULE: INDUSTRIAL APPLICATIONS

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe and generally design solar systems for various industrial applications.

(2) Generally assess the potential for solar energy impact in the industrial market.

RATIONALE:

The solar student will find a growing interest in solar energy for industrial use. This module discusses such use in canning/bottling, textile manufacturing, pulp and paper, and the dairy industry.

REFERENCES:

(1) Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Process Heat, DOE COO/2829-1, February 1977.

(2) Feasibility Evaluation: Solar Heated Textile Process Water, DOE SRO/0885-77/2/1, February 1977.

(3) Application of Solar Energy to the Supply of Industrial Process Hot Water, DOE SAN/1218-3, October 1976.

(4) Application of Solar Energy to Industrial Drying or Dehydration Process, DOE ORO/5121-1, March 1977.

(5) Research on the Application of Solar Energy to Industrial Drying or Dehydration Processes, DOE ORO/5123-1, March 1977.

(6) Application of Solar Energy to Continuous Belt Dehydration, DOE ORO/ 5119-1, April 1977.

UNIT TITLES:

(1) Building Applications

(2) Process Applications

VOCABULARY:

Thermal Energy
Solar Energy
Fossil Fuel
Energy Resource
Temperature
Space Heating
Domestic Water Heating
Process Hot Water
Space Cooling
Solar Collector
Warehouse

Insolation
Insulation
Collector Efficiency
Air System
Liquid System
Flat-Plate Collector
Concentrating Collector
Tracking Collector
Evacuated Tube
Reflector
Steam

Reference 1-6

Unit 1. Building Applications

- A. Industrial thermal energy applications by:
  - 1. End use (process hot water, steam, domestic hot water, space heat, space cooling, metal casting and refining)
  - 2. Fuel type (coal, oil, gas, electricity)
  - 3. Temperature range

Handout schematic of active and passive solar heating principles

- B. Potential for solar energy systems for industrial purposes by
  - 1. Temperature range of load
  - 2. Conventional fuel economics
  - 3. Solar usage projections

Handout of pictures and specifications of active and passive solar space heating systems

- C. Thermal energy requirements of office buildings and warehouses
- D. Design principles of active and passive solar systems for office buildings and warehouses

Reference 1-6

Unit 2. Process Applications

- A. Typical temperature and load requirements steam, hot water, and hot air in major industrial process:
  - 1. Canning (bottling)
  - 2. Textile manufacturing
  - 3. Pulp and paper
  - 4. Dairy products
- B. Layout and design of solar systems to supply process steam, hot water and hot air for:
  - 1. Canning/bottling
  - 2. Textile manufacturing
  - 3. Pulp and paper
  - 4. Dairy products

INSTRUCTOR ACTIVITY	Laboratory:
	Specify hot water requirements for a canning operation.
STUDENT ACTIVITY	Laboratory:
Exercise	Layout and size a solar system for providing hot water to a specified canning operation.
Laboratory Materials:	Drawing board and drafting equipment.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Briefly describe the theory of photovoltaic conversion of solar energy to electricity.

(2) Assemble and properly connect photovoltaic cells into a collector array.

(3) Design photovoltaic systems that are independent of utility supplied auxiliary electricity and systems that interface with utility supply (60 Hertz) electricity.

RATIONALE:

One of the more promising uses of solar energy is with the photovoltaic cell. Major breakthroughs and cost reductions in the field will present the solar student with a new dimension to his/her studies. The state-of-the-art in photovoltaics at this point is rapidly changing. Therefore, the purpose of this module is to acquaint the solar technician student with the technology, applications, and potential for photovoltaics as the state-of-the-art presently exists.

REFERENCES:

(1) Daniels, Yale, Direct Use of the Sun's Energy, 1964.

(2) Energy for Rural Development, National Academy of Science, 1976.

(3) Palfrey, Photovoltaic Power Generation, Van Nostrant Reinhold, 1978.

UNIT TITLES:

(1) Elements of Photovoltaic Power Systems

(2) Basic Theory and Performance of Solar Cells

(3) Solar Cells for Unconcentrated Systems

(4) Solar Cells for Concentrated Systems

(5) Economics of Photovoltaic Power Systems

VOCABULARY:

Energy
Power
Thermal Energy
Electrical Energy
Mechanical Energy
Electricity
Solar Energy
Energy Conversion
Transmission
Insolation
Efficiency
Concentrating Collector
Tracking Collector
Fresnel Lens
Photovoltaics
Pump
Battery
Energy Cell
Direct Current
Alternating Current
Inversion
Frequency Regulation
Voltage Regulation
Short Circuit
Open Circuit

Reference 1, Chap. 16 2 3, Chap. 1,2	Unit 1. Elements of Photovoltaic Power Systems A. Photovoltaic energy conversion B. Photovoltaic arrays C. Power conditioning D. Storage E. Present-day photovoltaic power systems
Reference 3, Chap. 3	Unit 2. Basic Theory and Performance of Solar Cells A. Solar cell equivalent circuit B. The short circuit photocurrent C. The open circuit photovoltage D. The fill factor
Reference 3, Chap. 4	Unit 3. Solar Cells for Unconcentrated Systems A. Conversion efficiency B. Silicon solar cells C. Cadmium sulfide solar cells D. Other materials E. Energy payback
Reference 3, Chap. 5	Unit 4. Solar Cells for Concentrated Systems A. Conversion efficiency B. Gallium arsenide cells C. Silicon cells
Reference 3, Chap. 6	Unit 5. Economics of Photovoltaic Power Systems A. System costs B. Electricity costs

INSTRUCTOR ACTIVITY

Laboratory:

Specify an average daily volume requirement for a solar powered irrigation system.

STUDENT ACTIVITY

Assignment:

Laboratory:

Size a photovoltaic power system for delivering the specified average daily volume of water.

INSTRUCTOR ACTIVITY	Laboratory: Assemble a test circuit to measure the power output and temperature of photovoltaic cells subjected to incident solar radiation.
STUDENT ACTIVITY	Laboratory:
Exercise I	Measure the power output of different types of photovoltaic cells as a function of incident radiation and cell temperature.
Laboratory Materials:	Photovoltaic cells, pyranometer, electrical loads, thermocouples, recorders, voltmeter, ammeter.
INSTRUCTOR ACTIVITY	Laboratory: Specify annual energy requirements for a remotely located residence.
STUDENT ACTIVITY	Laboratory:
Exercise II	Design a solar photovoltaic power system for a remotely located residence, estimate collector size, storage needs, and total annual energy supplied.
Laboratory Materials:	Drawing board and drafting equipment.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Describe possible future technological developments in solar and other energy conservation components and systems.

(2) Generally design annual cycle energy systems (ACES), "power tower" central power systems, and Rankine cycle heat engines.

RATIONALE:

Solar energy is not a new technology as the student has learned throughout the progression of his/her solar program. It is a continually changing field of study which holds new developments and new discoveries everyday. This module will discuss some of these new ideas for future solar applications. As such, this module serves only as a sample of what is known presently about solar future applications. This module should become outdated as new discoveries and technology progress.

REFERENCES:

(1) Daniels, Yale, Direct Use of the Sun's Energy, 1964.

(2) Beckman and Duffie, Solar Energy Thermal Processes, Wiley, 1974.

(3) Meinel and Meinel, Applied Solar Energy, Addison-Wesley, 1976.

(4) Kreider and Kreith, Solar Heating and Cooling, Hemisphere, 1977.

(5) Davis and Schubert, Alternate Natural Energy Sources in Building Design, Van Nostrand Reinhold, 1977.

(6) Energy for Rural Development, National Academy of Science, 1976.

(7) Solar Energy Handbook - Theory and Applications, Power Systems Group, Ametek, Inc., 1979.

(8) Metz and Hammond, Solar Energy In America, AAAS, 1978.

(9) Applications of Solar Technology of Today's Energy Needs, Volume 1, Office of Technology Assessment, Congress of U.S., 1978.

UNIT TITLES:

(1) Cooling Systems

(2) Solar Central Power Stations

VOCABULARY:

Absorption Cooling
Rankine Cycle
Vapor Compression
Vapor-Jet
Desiccant
Absorption
ACES
Evaporative Cooling
Photovoltaic Cell
Collector Array
Solar Collector
Mechanical Energy
Thermal Energy
Insolation
Insulation
Flat Plate Collector
Concentrating Collector
Tracking Collector
Reflector
Collector Efficiency
Battery
Energy Cell
Controls
Direct Current
Alternating Current
Inversion
Frequency Regulation
Voltage Regulation
Power Tower
Distributed System
Dish System
OTEC
Evaporation
Condenser
Overall Heat Transfer
Wind Generator
Capture Area
Speed
Velocity

Reference 1, Chap. 13
2, Chap. 13
4, Chap. 5
7, Chap. 6
9, Chap. XII

Unit 1. Cooling Systems
- A. Absorption
- B. Rankine cycle driven vapor compression
- C. Vapor jet
- D. Vacuum
- E. Desiccant
- F. Annual cycle energy system (ACES)

Reference 2, Chap. 15
3, Chap. 14-16
5, Chap. 6
6
8, Chap. 7-9
9, Chap. IX, X

Unit 2. Solar Central Power Stations
- A. Land based
  - 1. Power tower
  - 2. Distributed systems
  - 3. Dish system
- B. Space based
  - 1. Photovoltaic
  - 2. Rankine cycle
  - 3. Transmitting and receiving
- C. Ocean and air
  Principle of operation of generating mechanical power from temperature gradients in the ocean and air
- D. Wind generating systems
  power available as a function of wind speed, capture area, and blade design

INSTRUCTOR ACTIVITY

Laboratory:

Specify climate and load conditions for a residential ACES system.

STUDENT ACTIVITY

Exercise I

Laboratory:

Design an ACES system for the specified climate and load conditions.

INSTRUCTOR ACTIVITY

Laboratory:

Assemble collector and delivery components of a model power tower system.

STUDENT ACTIVITY

Exercise II

Laboratory:

Using small mirrors, model a power tower system and measure the temperature at the focal point. Estimate the concentration ratio. Calculate the minimum land area needed for a 100 megawatt peak output power station.

Laboratory Materials: Small mirrors, small pump and water circulation system, themocouple, and recorder.

INSTRUCTOR ACTIVITY

Laboratory:

Specify temperatures available for an OTEC system, and average overall heat transfer coefficients for the heat exchangers.

STUDENT ACTIVITY:

Assignment:

Laboratory:

Calculate the condenser and evaporator heat transfer rates and the pumping power required for a Rankine cycle ocean thermal energy conversion system delivering 1 megawatt of mechanical power. Make a rough estimate of the heat exchange area needed in each of the evaporators and condensers.

NON-RESIDENTIAL APPLICATIONS AND FUTURE TECHNOLOGY

Representative Labs

MODULE: Agricultural, Commercial, and Industrial Power Demands

Lab 1: Collector Efficiency Test

Instructor Activities:

Inspect laboratory equipment to determine if the collector test procedure described in ASHRAE 93-77 can be followed. If not, modify the directions as appropriate for the equipment on hand.

Scope:

Various standards for solar collector performance testing and for the design and installation of solar equipment are now being drafted in several countries. Working groups and professional organizations such as International Energy Agency (IEA), National Bureau of Standards (NBS), and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), have developed a standard for collector performance testing and evaluation. The method used to develop the collector performance curve for steady state conditions at low levels of radiation intensity is known as the Hottel-Whillier Equation. Utilizing performance curves such as these is very valuable when comparing similar types of collectors. This comparative evaluation also requires attention to the effect of other components of a solar energy system because the system determines the conditions under which collectors must operate.

Most manufacturers of solar collectors provide data on the efficiencies of their equipment. Some of this information is derived from measurements made by the manufacturers. Other performance data which may be available are produced by independent testing organizations. Since the efficiency of a solar collector is highly dependent on the test conditions, meaningful data require full specification of the significant variables.

The student working with a team will, to the best of their ability, replicate a standard testing process for determining the thermal performance of a collector and report their findings back to the class.

Laboratory Materials:

Collectors, pyranometer, mixing valve, temperature sensors, heat exchanger, pressure gauges, bleed valves, flow meters, pumps, mixing valve, storage tank, assorted copper pipe and fittings, ASHRAE 93-77.

Process:

Using ASHRAE 93-77 recommended apparatus set up as found on page 8, Figure 1 of the ASHRAE 93-77 Document, complete a laboratory steady state evaluation of a minimum of two commercial and one non-commercial collector. For this closed loop efficiency test on a flat plate collector use a standardized low temperature of 85°F (47.2°C) and a standardized medium temperature of 130°F (72.2°C).

Student Activities:

Submit the data collected using the ASHRAE 93-77 collector efficiency graph format. Submit your subjective conclusions on collector efficiency and its relationship to collector temperatures.

NOMENCLATURE

a, b = constants used in incident angle modifier equation, dimensionless

A = cross-sectional area, m^2 - (ft^2)

A_a = transparent frontal area for a flat plate collector or aperture area for a concentrating collector, m^2(ft^2)

A_g = gross collector area, m^2(ft^2)

A_n = area of nozzle, m^2(ft^2)

A_r = absorbing area of a flat plate collector or the receiving area of a concentrating collector, m^2(ft^2)

b_0 = constant used in incident angle modifier equation, dimensionless

C_A = effective heat capacity of the solar collector, J/ $^{\circ}$C(Btu/F)

C_n = nozzle coefficient of discharge, dimensionless

c_p = specific heat of the transfer fluid, J/(kg $\cdot$ $^{\circ}$C) (Btu/(lbm $\cdot$ F))

D_n = nozzle throat diameter, m(ft)

f_t = temperature factor for calculation of nozzle Reynolds number, dimensionless

F' = absorber plate efficiency factor, dimensionless

F_R = solar collector heat removal factor, dimensionless

I = solar irradiation, W/m^2 (Btu/(hr $\cdot$ ft^2))

I_D = direct solar irradiation component W/m^2 (Btu/(hr $\cdot$ ft^2))

I_{DN} = direct normal solar irradiation, W/m^2 (Btu/(hr $\cdot$ ft^2))

I_d = diffuse solar irradiation incident upon the aperture plane of collector, W/m^2 (Btu/(hr $\cdot$ ft^2))

I_{sc} = solar constant, 1353 W/m^2 (429.2 Btu/(hr $\cdot$ ft^2))

I_t = total solar irradiation incident upon the aperture plane of collector, W/m^2 (Btu/(hr $\cdot$ ft^2))

K = factor defined by equation (8.7), dimensionless

$K_{\alpha I}$ = incident angle modifier, dimensionless

LST = local standard time, decimal hours

LSTM = local standard time meridian, deg

AST = apparent solar time, decimal hours

$\underline{m}$ = air mass, dimensionless

$\dot{m}$ = mass flow rate of the transfer fluid, kg/s (lbm/hr)

N_{Re} = Reynolds number, dimensionless

P_{th} = theoretical power required to move the transfer fluid through the collector, W(hp)

p_n = absolute pressure at the nozzle throat, Pa(lbf/in^2)

p_v = velocity pressure at the nozzle throat or the static pressure difference across the nozzle, Pa(lbf/in^2)

Δp = pressure drop across the collector, Pa(lbf/in^2)

Δp_n = pressure drop across the nozzle, Pa(lbf/in^2)

Q_m = measured air flow rate, m^3/s(ft^3/min)

Q_s = standard air flow rate, m^3/s(ft^3/min)

q_u = rate of useful energy extraction from the collector, W(Btu/hr)

t_a = ambient air temperature, $^{\circ}$C(F)

t_f = average fluid temperature, $^{\circ}$C(F)

$t_{f,e}$ = temperature of the transfer fluid leaving the collector, $^{\circ}$C(F)

$t_{f,e,initial}$ = temperature of transfer fluid leaving the collector at the beginning of a specified time period, °C(F)

$t_{f,e,T}$ = temperature of the transfer fluid leaving the collector at a specified time, °C(F)

$t_{f,i}$ = temperature of the transfer fluid entering the collector, °C(F)

t_p = average temperature of the absorbing surface for a flat plate collector, °C(F)

t_r = average temperature of the absorbing surface for a concentrating collector, °C(F)

Δt = temperature difference, °C(F)

U_L = solar collector heat transfer loss coefficient, $W/(m^2 \cdot {}^\circ C)$ $(Btu/(hr \cdot ft^2 \cdot F))$

V_a = velocity of the air at the nozzle throat, m/s (ft/min)

v_n = specific volume of the air at the nozzle at standard barometric pressure, m^3/kg dry air (ft^3/lbm dry air)

v'_n = specific volume of air at the nozzle per unit mass of air-water vapor mixture, m^3/kg (ft^3/lbm)

w = density, kg/m^3 (lbm/ft^3)

W_n = humidity ratio at the nozzle, kg H_2O/kg dry air (lbm H_2O/lbm dry air)

α = absorptance of the collector absorber surface for solar radiation

Γ = fraction of specularly reflected radiation from the reflector or refracted radiation which is intercepted by the solar collector absorbing surface

γ = collector-solar azimuth, deg

θ = angle of incidence between direct solar rays and the normal to the collector surface or to the aperture, deg

β = solar altitude angle, deg

ϕ = solar azimuth angle, deg

ψ = collector azimuth angle, (measured from the south in the horizontal plane), deg

η_g = collector efficiency based on gross collector area, %

λ = wavelength, μm

ρ = specular reflectance of the solar collector reflector

T = time, decimal hours or seconds

τ = transmittance of the solar collector cover plate, dimensionless (if no cover plate is used, $\tau = 1.0$)

$(\tau\alpha)_e$ = effective transmittance-absorptance product, dimensionless

$(\tau\alpha)_{e,n}$ = effective transmittance-absorptance product at normal incidence

T_1, T_2 = time at the beginning and end of a test period, decimal hours

Σ = collector tilt from the horizontal, deg

ASHRAE STANDARD 93-77

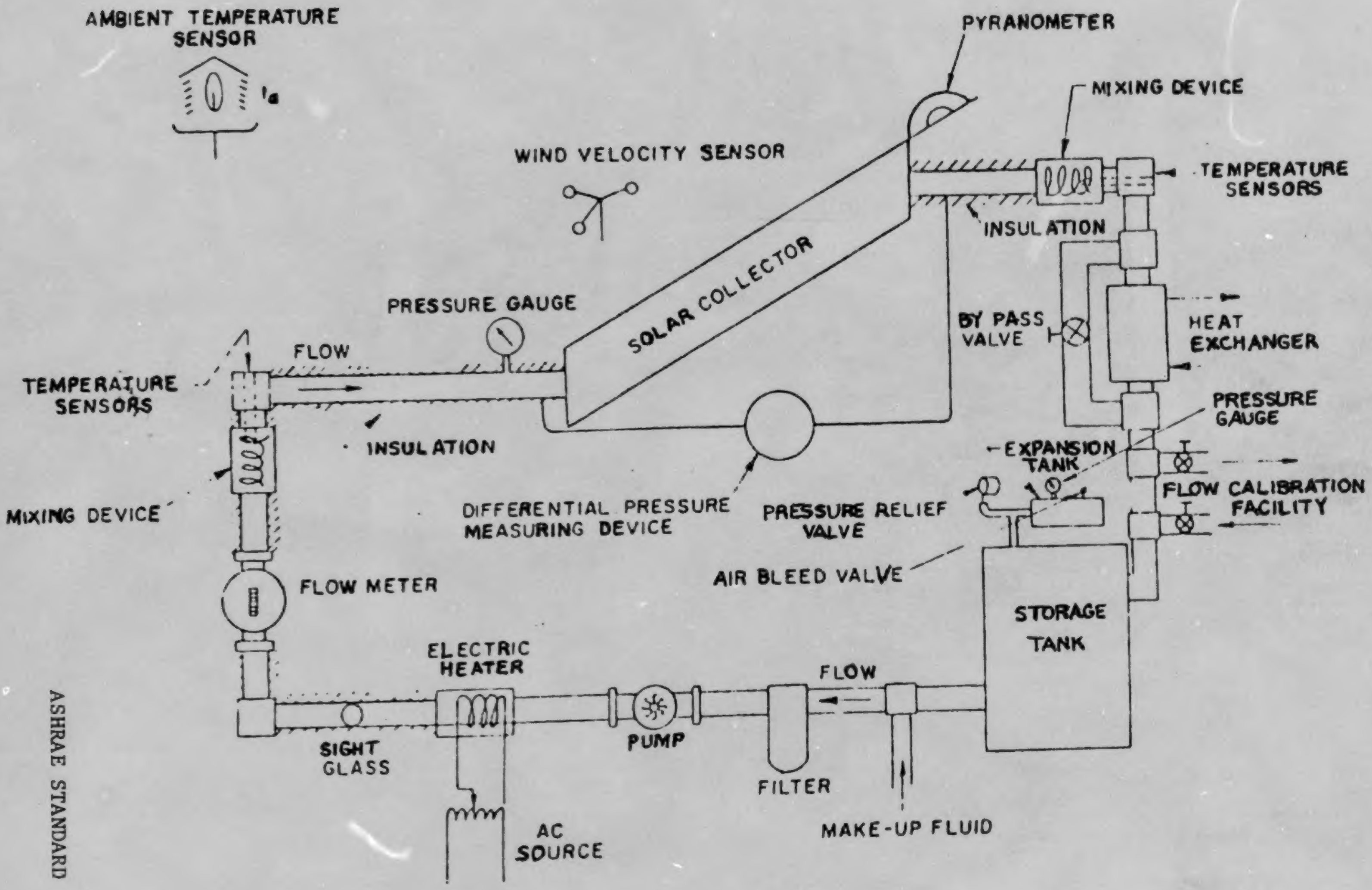

AMBIENT TEMPERATURE SENSOR
t_a
WIND VELOCITY SENSOR
PYRANOMETER
MIXING DEVICE
TEMPERATURE SENSORS
INSULATION
SOLAR COLLECTOR
PRESSURE GAUGE
FLOW
TEMPERATURE SENSORS
INSULATION
MIXING DEVICE
BY PASS VALVE
HEAT EXCHANGER
PRESSURE GAUGE
EXPANSION TANK
FLOW CALIBRATION FACILITY
DIFFERENTIAL PRESSURE MEASURING DEVICE
PRESSURE RELIEF VALVE
AIR BLEED VALVE
FLOW METER
STORAGE TANK
ELECTRIC HEATER
FLOW
SIGHT GLASS
PUMP
FILTER
MAKE-UP FLUID
AC SOURCE

Fig. 1 Closed-Loop Testing Configuration for the Solar Collector when the Transfer Fluid is a Liquid

TABLE 2
Data and Information to be Reported

GENERAL INFORMATION

Manufacturer or Project Name ______________________________

Collector Model No. ______________________________

Construction details of the collector:

aperture dimensions and area, m and m^2 (ft and ft^2)

____

gross dimensions and area, m and m^2 (ft and ft^2)

____

dimensions and area of absorbing surface, m and m^2 (ft and ft^2)

____

cover plate*, dimensions, materials, optical properties (if known) ______________________________

reflector or refractor*, dimension, materials, optical properties (if known) ______________________________

Absorber plate, dimensional layout and configuration of flow path, absorptance for short wave radiaton (if known), emittance for long wave radiation (if known), description of coating (including maximum allowable temperature °C(F), (if known)

____

air space(s)*, thickness, m(ft) and description of contained gas or construction ______________________________

insulation*, material, thickness, m(ft), thermal properties

____

Transfer fluid used and its thermal and physical properties

____

Weight of collector, based on gross area, kg/m^2 (lbm/ft^2)

____

---

*if applicable

Volumetric capacity of the collector based on gross area if designed to operate with a liquid as the transfer fluid, m^3/m^2 (ft^3/ft^2)

____

____

Normal operating temperature range, $^{o}C(F)$ ______________

Minimum transfer fluid flow rate, kg/s (lbm/hr) ______________

Maximum transfer fluid flow rate, kg/s (lbm/hr) ______________

Maximum operating pressure, Pa (lbf/ft^2) ______________

Description of apparatus, including flow configuration and instrumentation used in testing (include photographs)

____

Description of the mounting of the collector for testing

____

____

Location of tests (longitude, deg; latitude, deg; and elevation above sea level, m(ft)

____

COLLECTOR THERMAL EFFICIENCY

A plot of the efficiency versus $\frac{t_{f,i} - t_a}{I_t}$ ______________

____

An equation for the efficiency curve ______________

For each data point:

$\dot{m}$ ______________ kg/s (lbm/hr)

c_p ______________ $J/(kg/^{o}C)(Btu/(lbm \cdot F))$

T_1, time of starting test ______________ LST(AST)

T_2, time of ending test ______________ LST(AST)

$\int_{t_1}^{t_2} (t_{t,e} - t_{f,i})dT$ ______________ $^{o}C \cdot s(F \cdot hr)$

$\int_{t_1}^{t_2} I dT$ ______________ $J/m^2(Btu/ft^2)$

pressure drop across the solar collector ______________ $Pa(lbf/ft^2)$

collector tilt angle, ________________________________ deg

collector azimuth angle (as a function of time if movable)

____ deg

incident angle ____ deg

inlet fluid temperature, $t_{f,i}$ ______________________ $^{o}C(F)$

exit fluid temperature, $t_{f,e}$ ______________________ $^{o}C(F)$

percentage of incident radiation that is diffuse ____________ %

wind speed near the collector surface or aperture

____ m/s(mph)

wind direction near the collector surface or aperture

____ deg from north

COLLECTOR TIME CONSTANT

Method (1) or Method (2) ____________________________

collector time constant ____________________________ min.

a plot of $t_{f,e}$ versus time ____________________________

a plot of $t_{f,i}$ versus time ____________________________

a plot of t_a versus time ____________________________

$\dot{m}$ ____ kg/s(lbm/hr)

T_1, time of starting test ________________________ LST(AST)

T_2, time of ending test __________________________ LST(AST)

description of shield used to abruptly reduce insolation in method (1) or technique to abruptly reduct $t_{f,i}$ in method (2)

____

____

____

if inlet temperature cannot be controlled to equal the ambient temperature, provide the following additional data used to calculate the time constant:

$(A_a/A_g)F_RU_L$ ______________________ $W/(m^2 \cdot {}^{o}C)(Btu/(hr \cdot ft^2 \cdot F))$

c_p ______________________________ $J/(kg \cdot {}^{o}C)(Btu/(lbm \cdot F))$

A_g ______________________________ $m^2(ft^2)$

COLLECTOR INCIDENT ANGLE MODIFIER

method (1) or method (2) ______________________________

a plot of $K_{\sigma\tau}$ versus θ ______________________________

$A_a/A_g)F_R(\tau\alpha)_{e,n}$ ______________________________

For each data point:

$\dot{m}$ ______________________________ kg/s(lbm/hr)

c_p ______________________________ J(kg • °C)(Btu/(ibm • F))

inlet fluid temperature, $t_{f,i}$ ______________________________ °C(F)

exit fluid temperature, $t_{f,e}$ ______________________________ °C(F)

ambient air temperature, t_a ______________________________ °C(F)

T_1, time of starting test ______________________________ LST(AST)

T_2, time of ending test ______________________________ LST(AST)

$\int_{t_1}^{t_2}(t_{f,e}-t_{f,a})dT$ ______________________________ $^{\circ}C \cdot s(F\ ^6\ hr)$

$\int_{t_1}^{t_2} I\,dT$ ______________________________ $J/m^2(Btu/ft^2)$

collector tilt angle ______________________________ deg

collector azimuth angle ______________________________ deg

incident angle ______________________________ deg

percent of incident radiation that is diffuse ______________ %

wind speed near the collector surface or aperture

______________________________ m/s(mph)

wind direction near the collector surface or aperture

______________________________ deg from north

MODULE: Agricultural, Commercial, and Industrial Power Demands

Lab 2: Collector Efficiency Test

Instructor Activities:

Inspect laboratory equipment to determine if the collector test procedure described in Ashrae 93.77 can be followed. If not, modify the directions as appropriate for the equipment on hand.

Scope:

Various standards for solar collector performance testing and for the design and installation of solar equipment are now being drafted in several countries. Working groups and professional organizations such as International Energy Agency (IEA), National Bureau of Standards (NBS), and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), have developed a standard for collector performance testing and evaluation. The method used to develop the collector performance curve for steady state conditions at low levels of radiation intensity is known as the Hottel-Whillier Equation. Utilizing performance curves such as these is very valuable when comparing similar types of collectors. This comparative evaluation also requires attention to the effect of other components of a solar energy system because the system determines the conditions under which collectors must operate.

Most manufacturers of solar collectors provide data on the efficiencies of their equipment. Some of this information is derived from measurements made by the manufacturers. Other performance data which may be available are produced by independent testing organizations. Since the efficiency of a solar collector is highly dependent on the test conditions, meaningful data require full specification of the significant variables.

The student working with a team will, to the best of their ability, replicate a standard testing process for determining the thermal performance of a collector and report their findings back to the class.

Laboratory Materials:

Collectors, pyranometer, mixing valve, temperature sensors, heat exchanger, pressure gauges, bleed valves, flow meters, pumps, mixing valve, storage tank, assorted copper pipe and fittings, Ashrae 93.77.

Process:

Using Ashrae 93.77 recommended apparatus set up as found on page 8, Figure 1 of the Ashrae 93.77 Document, complete a laboratory steady state evaluation of a minimum of two commercial and one non-commercial collector. For this closed loop efficiency test on a flat plate collector use a standardized low temperature of 85°F (47.2°C) and a standardized medium temperature of 130°F (72.2°C).

Student Activities:

Complete Ashrae 93.77 Collector Efficiency Test begun in Lab Assignment 1.

MODULE: Agricultural Applications

Lab 3: Design, Active Solar Livestock Shelter

Instructor Activities:

Specify type and population of an animal shelter to be solar heated.

Scope:

The most economical approach to heating a structure is to do it as simple as possible, using existing materials and technology and, of course, letting nature do the greatest percentage of the work. As in residential and commercial architecture, a direct solar approach has major advantages including simplicity, low cost, reliability, and durability. In the design and locating of out buildings, (animal shelters), keep in mind the simple concept of proper exposure. Locate them so that sunlight can enter the structures during the winter months and heat them directly; during the summer months when the sun is further up on its axis, the buildings should be shaded by the buildings overhang, thus staying relatively cool.

The size, shape, height, color, and orientation of a building all have an effect on how much sun it receives at various times of the year. Depending on your location, it may be more necessary to optimize the building for heating or cooling performance. In most locations in the Northern Hemisphere, it is estimated that solar gain can be as much as 25 times the winter solar gain. Thus, supporting the decision to specify that the east and west walls and the roof of a structure be minimized, since they collect heat, predominately when it is undesirable. South walls and windows have the most potential as solar collectors for the animal shelter space heating.

The student working with a team should select a small animal application and, after reviewing that animal's habits, design an appropriate shelter.

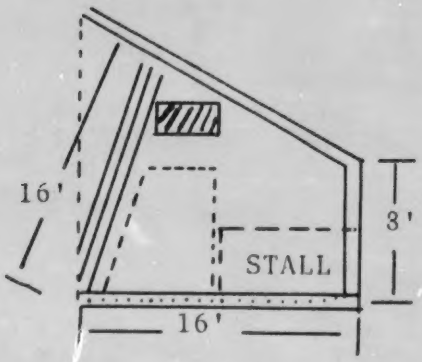
Laboratory Materials:

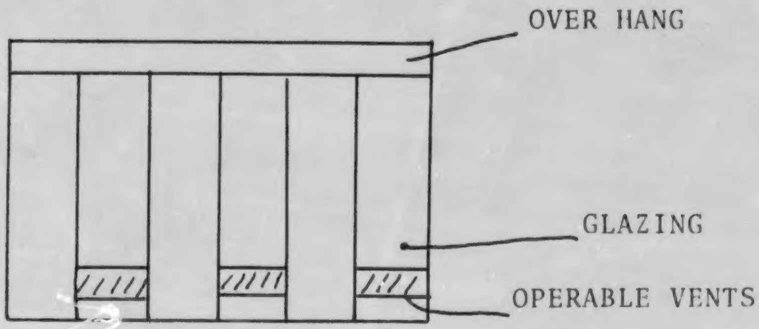
Grid paper, calculator, drawing board and related drafting equipment, design specifications.

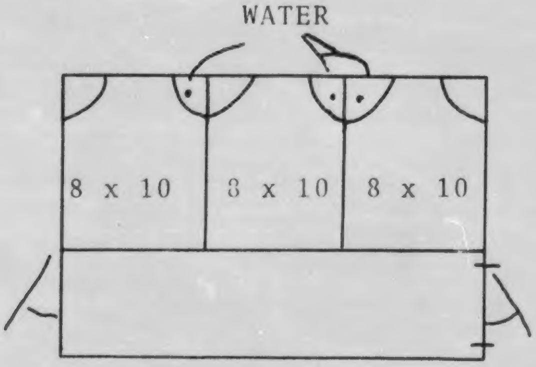
Process:

Utilizing information available in the student guide, design an appropriate active solar animal shelter. Show design and list design calculations.

PASSIVE HORSE BARN


16'
3'
STALL
16'


OVER HANG
GLAZING
OPERABLE VENTS


WATER
8 x 10
8 x 10
8 x 10

MODULE: Agricultural Applications

Lab 4: Design, Forced-Air Solar Grain Drying System

Instructor Activities:

Specify a grain type and associated drying load for a solar drying system.

Scope:

Crop drying is divided into two major categories: grains, and leafy or high moisture crops. For this lab, the author has selected a grain problem. As discussed, the major role of solar energy in the crop drying process is to produce an accelerated diffusing of moisture into a flowing air stream with the sole chore of solar energy being the increasing of the heat of that specific airstream.

Common to the industry is a single problem, the design must keep the design heat either very low or very high. A temperature in between could accelerate spoilage.

The student working with a design team will: select a low moisture grain, and identify its moisture levels, both in the field and processed. With this data, the design team will design a solar crop drying device.

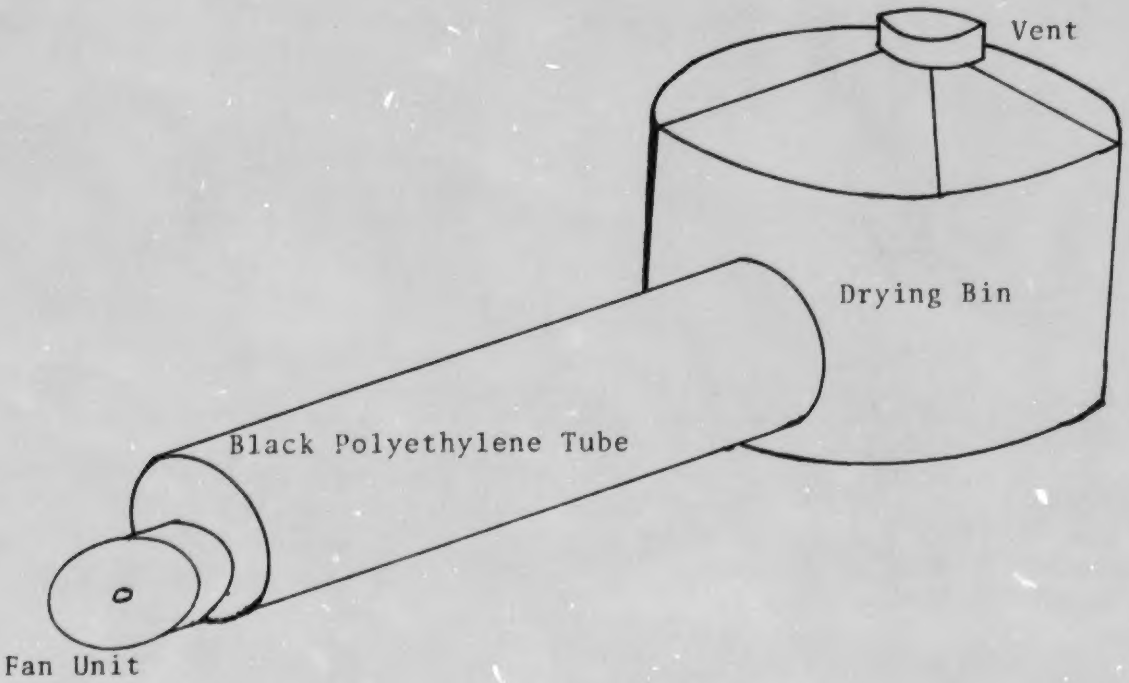
Laboratory Materials:

Grid paper, calculator drawing board and related drafting equipment, design specifications.

Process:

Utilizing available information located in the student guide, design an appropriate active grain dryer.

EXAMPLE OF A CROP DRYER



Latitude	45	deg
Energy income	2.6×10^4	kJ/m^2d
Energy income (noon hour)	2.4×10^3	kJ/m^2h
Percentage of possible sunshine	80	%
Utilization factor	100	%
Collector efficiency	0.25	-
Collector yield	5.2×10^3	kJ/m^2d
Collector yield (noon hour)	0.6×10^3	kJ/m^2h
Mass of air to be heated	4.3×10^3	kg/h
Heat required for 6C° rise (1.04 J/gC°)	2.7×10^4	kJ/h
Collector area required	45	m^2
Tube length (1.0 m diameter)	45	m
Equivalent energy from collector	1.09×10^2	kWh/d
Value of heat at $0.05/kWh	3.25	$/d
Value of heat in 60-day season	195.00	$/season
Value of collector	4.34	$/$m^2$y

MODULE: Agricultural Applications

Lab 5: Design and Construct Model Greenhouse with Storage

Instructor Activities:

Review green house design principles. Specify location, size, and load for a model green house.

Scope:

The term solar greenhouse generalizes those greenhouses whose heating and lighting requirements are largely provided by the sun. Most solar greenhouses collect and store solar energy for heating for heating and, by design, are insulated to retain this heat for use at night and during periods of cloudy days. As in residential and commercial applications, the greenhouse solar collection storage systems could be divided into two main types: Passive and Active. The typical passive solar greenhouse utilizes rock walls, water containers, and water pools open to direct solar insolation. The passive solar greenhouse, most commonly discussed in solar applications, would be the attached. The house/commercial attached solar greenhouse is designed to deliver more heat to the attached structure. Then, that structure's returns at night make it a positive gain application.

The student working with a design team should be assigned an option to design a freestanding or a structure-attached solar greenhouse. To best convey the design concept, the team should construct their design.

Laboratory Materials:

Grid paper, calculator, drawing board and related drafting equipment, design specifications, cardboard, box knife, glue set.

Process:

Design and construct, utilizing available information located in the student guide, a model solar greenhouse with some type of thermal energy storage.

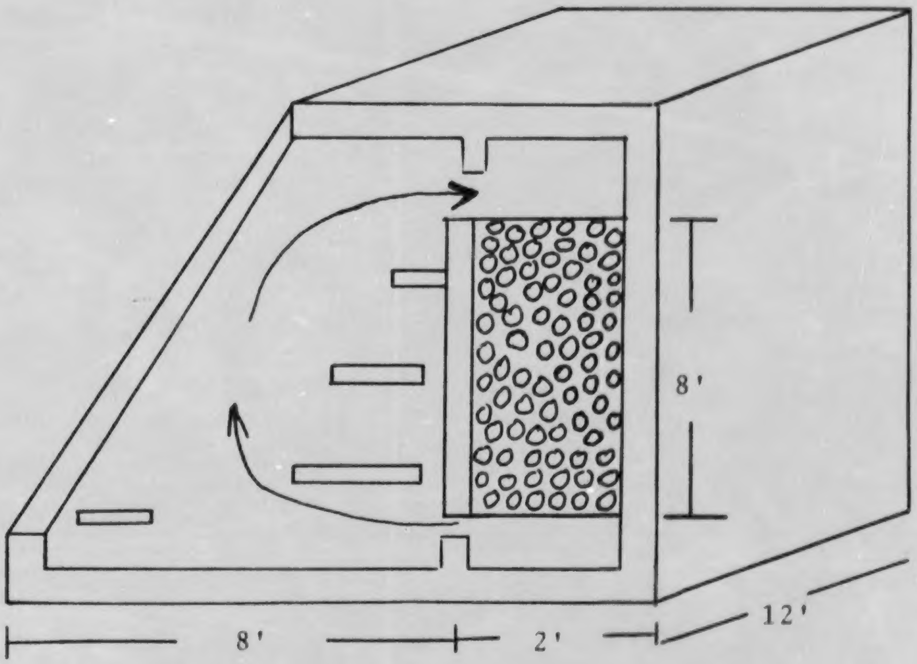
AN ATTACHED GREENHOUSE

I. Purpose.
  A. Heating of SE Bedroom & Sewing Study Room.
  B. To Start Plants for Garden.
  C. Winter Food Production.
  D. To Exercise a Greenthumb.
  E. To Contemplate the Basic Joy of Living Upon Arising in Morning.
  F. To Provide an Ideal Place for Procrastination.

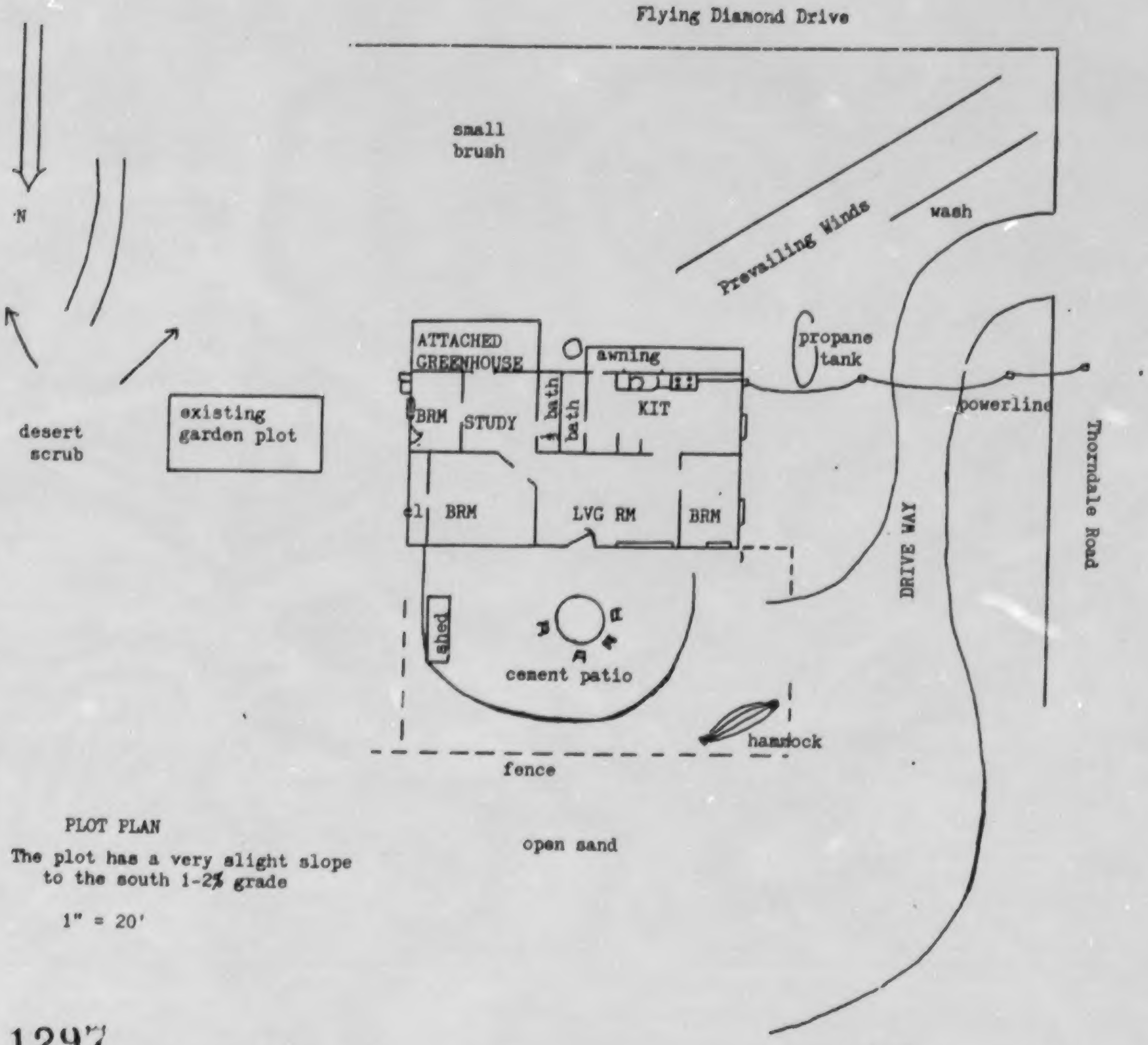
MATERIALS LIST

Linear Ft.	Pcs.	Size	Description
	9	4′ x 8′	1/2" Plywood, S.O.S.
	4	4′ x 8′	5/8" Exterior Grade Plywood
	3	4′ x 8′	5/8" Roof Sheathing
10′	3	2 x 2	#2 Doug Fir - Door Sandwich
12′	3′	2 x 8	#2 D.F. Sill Plate
4′	1	4 x 4	Door Header #2 D.F.
14	6	2 x 4	#2 D.F. Studs
10′	2	2/6	Ledger #2 D.F.
8′	44	2 x 4	#2 D.F. Stud
8′	2	2 x 2	#2 D.F. Vent Sandwich
10′	2	2 x 4	Rough-Sawn Facia #2 D.F.
8′	10	1 1/2"	Redwood Trim
8′	6	4"	Redwood Trim
	650	24"	3 1/2" Foil Backed Fiberglass Insulation
	110	24"	1" Fiberglass Insulation
	6	4′ x 4′	1 1/2" High R Sheathing
	400		Polystyrene 2"
	4	various	Vents
20′	1 roll	8"	Metal Flashing Flat
8′	1	1 1/2"	Corner Flashing (Dripedge)
	11	2 x 4	Simpson Joist Hangens
	6 doz.	8 x 8 x 16	Concrete Block
	1/2 doz.	8 x 8 x 8	Concrete Block
	12 doz.	4 x 4 x 10	Red Bricks or Equivalent
	850		Chicken Wire
			Cement Mortar
			Stucco Material
	2	bundles	White Shingles
	1	roll	Roofing Paper
55′		48"	Filon Glazing
			'Geocel' or Silicon Caulk
	1 doz.	6"	'L' Bolts & Nuts
			8 Penny Nails
			16 Penny Nails
			Roofing Nails
			16 Penny Galvanized

Linear Ft.	Pcs.	Size	Description
	5	1/2"	Bolts to Hold Rafter Ledger
			Hardware for Doors & Vents
			6 Penny Finish Nails
			6 Mil Polyethylene for Vapor Barrier
			8 Penny Finish Galvanized
			Wood Adhesive White Glue
			White Paint
			Copper Napthenate



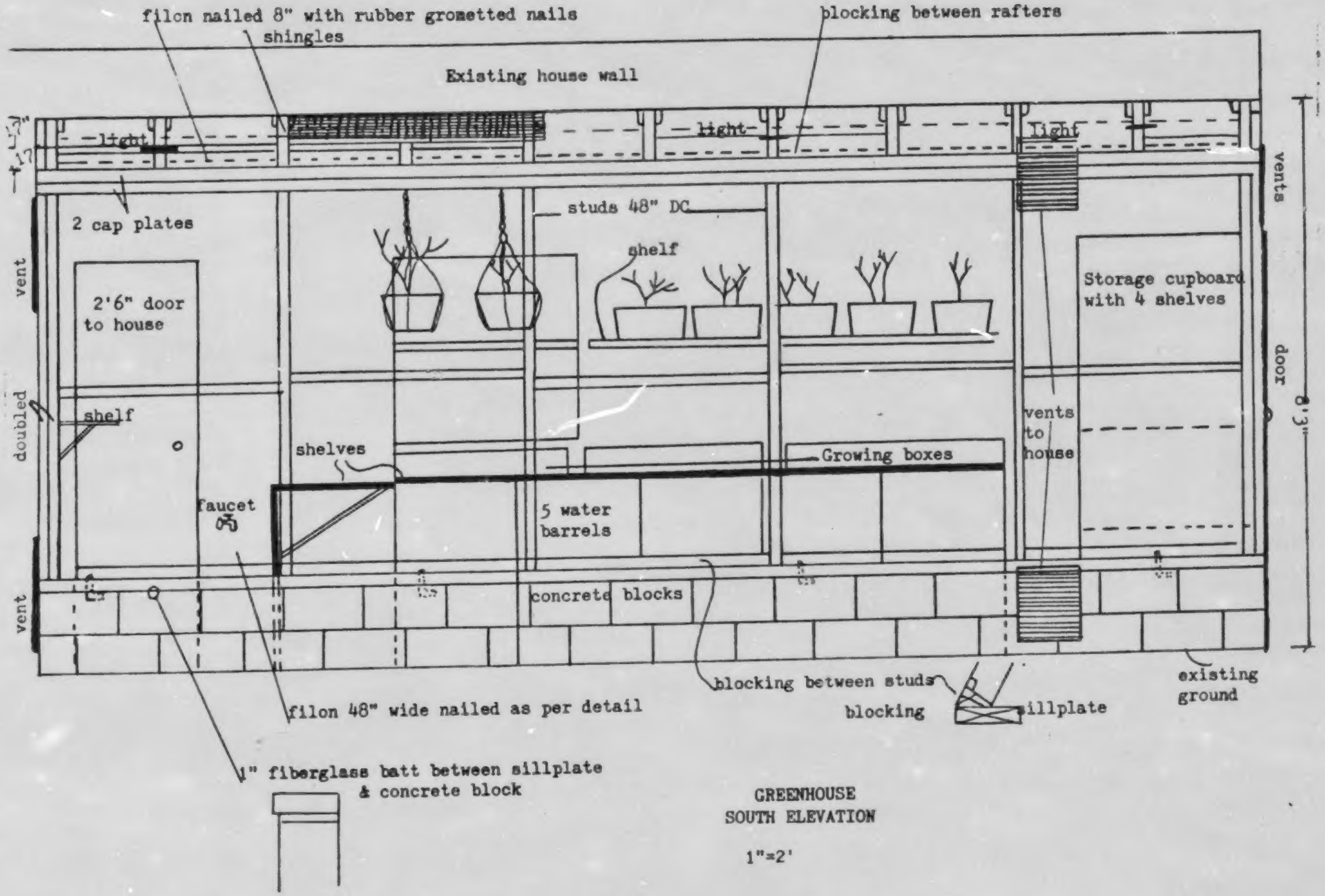
AN EXAMPLE OF AN ATTACHED GREENHOUSE


Flying Diamond Drive
small brush
N
Prevailing Winds
wash
desert scrub
existing garden plot
ATTACHED GREENHOUSE
awning
propane tank
powerline
BRM
STUDY
bath
bath
KIT
BRM
LVG RM
BRM
DRIVE WAY
Thorndale Road
shed
cement patio
hammock
fence
open sand

PLOT PLAN

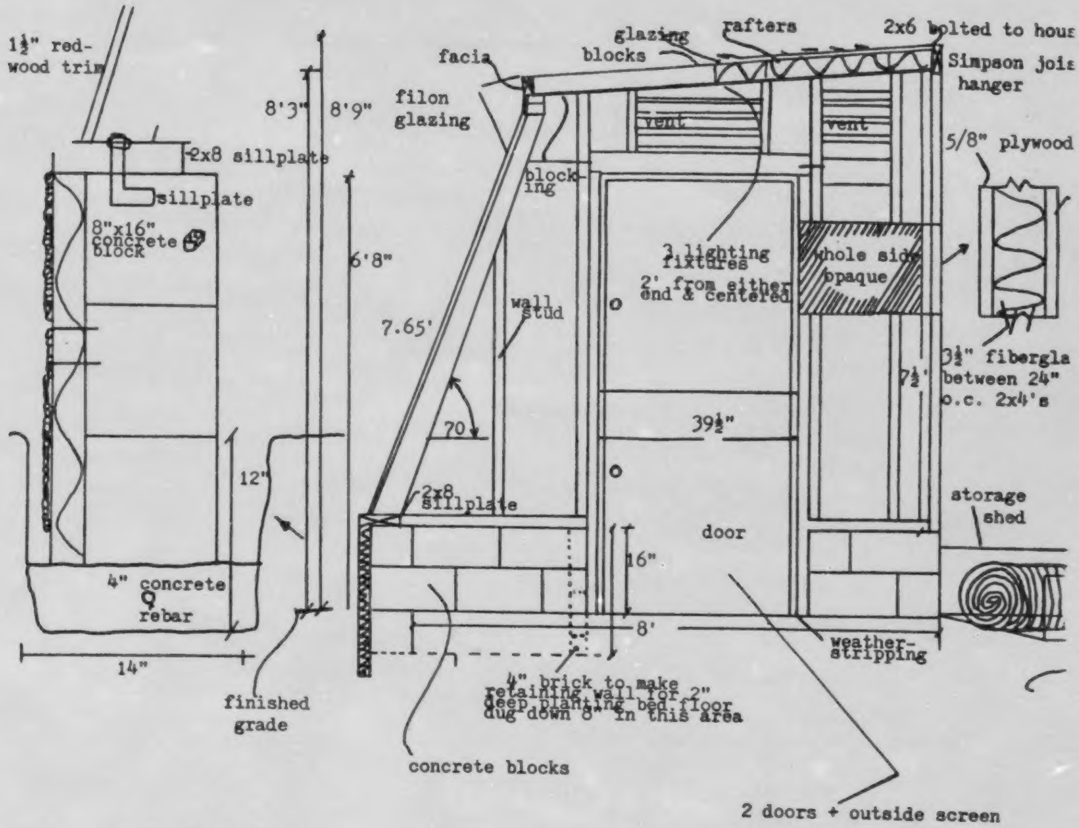
The plot has a very slight slope to the south 1-2% grade

1" = 20'


filon nailed 8" with rubber grommetted nails
shingles
blocking between rafters
Existing house wall
light
light
light
2 cap plates
studs 48" OC
shelf
vent
2'6" door to house
doubled
shelf
shelves
faucet
5 water barrels
Growing boxes
vents to house
Storage cupboard with 4 shelves
vents
door
8'3"
vent
concrete blocks
blocking between studs
blocking
sillplate
existing ground
filon 48" wide nailed as per detail
1" fiberglass batt between sillplate & concrete block

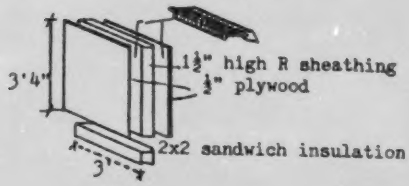
GREENHOUSE
SOUTH ELEVATION

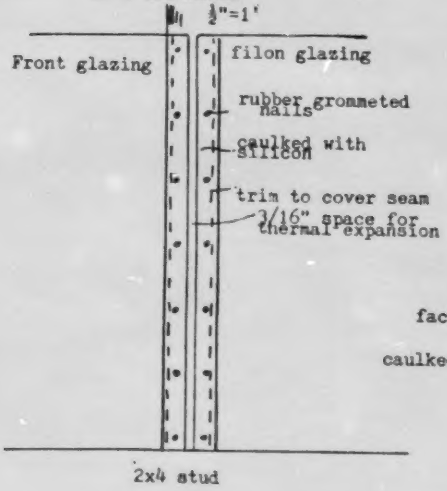
1"=2'

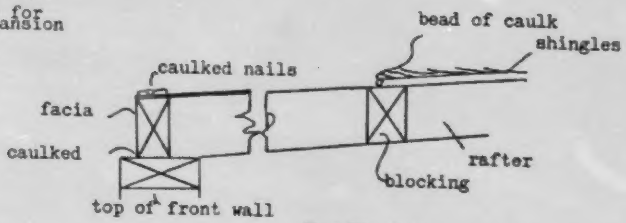

1½" red-wood trim
2x8 sillplate
sillplate
8"x16" concrete block
12"
4" concrete
rebar
14"
8'3"
8'9"
6'8"
finished grade
facia
filon glazing
glazing blocks
rafters
2x6 bolted to hous
Simpson jois hanger
vent
vent
blocking
5/8" plywood
3 lighting fixtures 2' from either end & centered
whole side opaque
wall stud
7.65'
70
3½" fibergla between 24" o.c. 2x4's
7½'
39½"
2x8 sillplate
16"
door
storage shed
8'
weather-stripping
4" brick to make retaining wall for 2" deep planting bed floor dug down 8" in this area
concrete blocks
2 doors + outside screen

GREENHOUSE

EAST ELEVATION ½"=1'


3'4"
1½" high R sheathing
½" plywood
2x2 sandwich insulation
3"

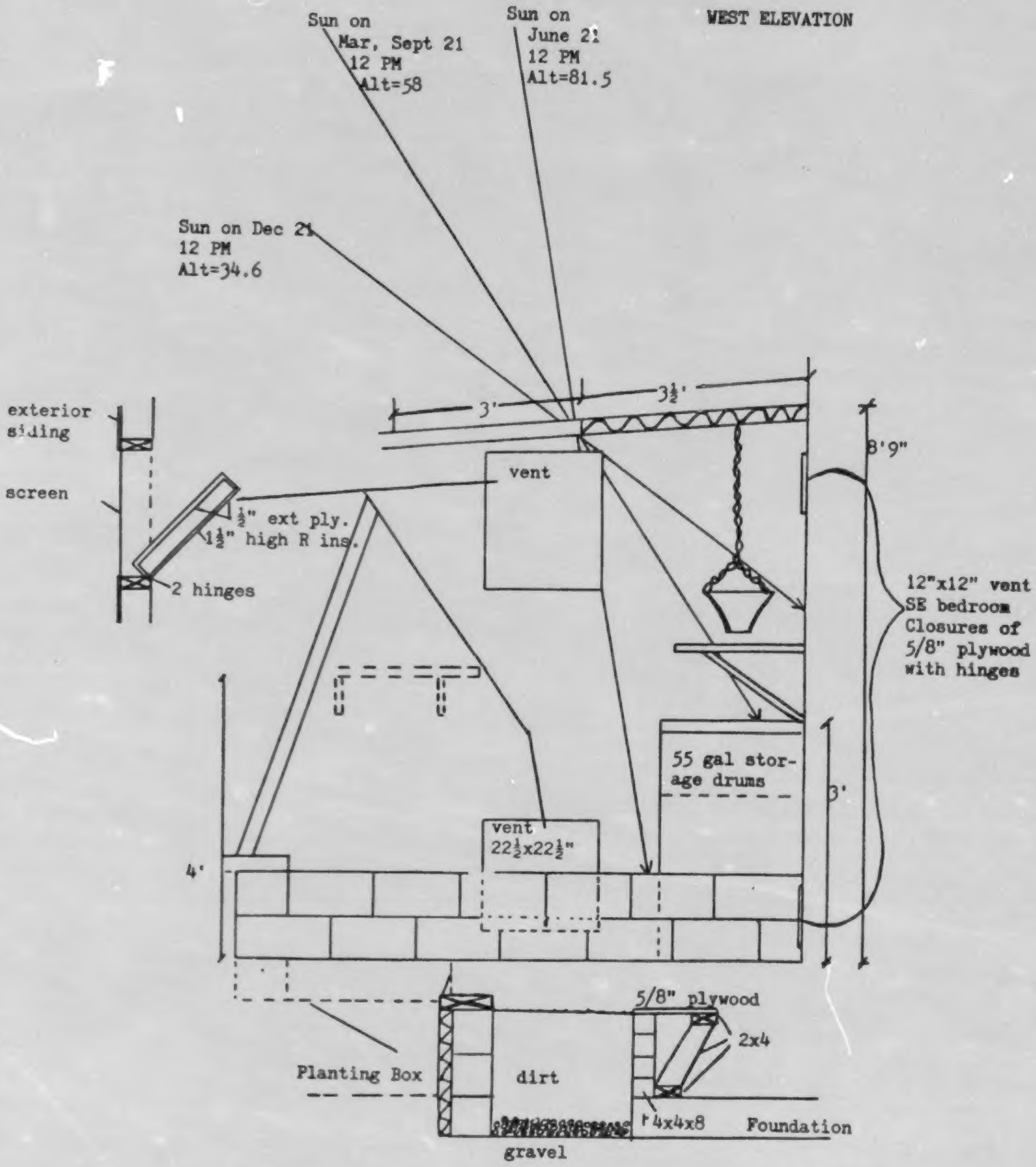

Front glazing
filon glazing
rubber grommeted nails
caulked with silicon
trim to cover seam
3/16" space for thermal expansion
2x4 stud

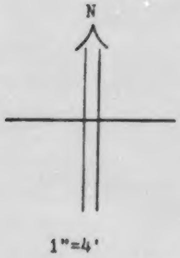

bead of caulk
shingles
caulked nails
facia
caulked
rafter
blocking
top of front wall

Top Glazing

GREENHOUSE

WEST ELEVATION


Sun on Mar, Sept 21 12 PM Alt=58
Sun on June 21 12 PM Alt=81.5
Sun on Dec 21 12 PM Alt=34.6
3'
3½'
8'9"
vent
exterior siding
screen
½" ext ply.
1½" high R ins.
2 hinges
12"x12" vent SE bedroom Closures of 5/8" plywood with hinges
55 gal storage drums
3'
4'
vent 22½x22½"
5/8" plywood
2x4
Planting Box
dirt
4x4x8
Foundation
gravel



ATTACHED GREENHOUSE

TOP VIEW

Venting

Upper West Side = 3.5
Upper East Side = 3.2
Upper Door = 10.2
16.9

Lower West Side = 3.5
Lower Door = 10.2
13.7

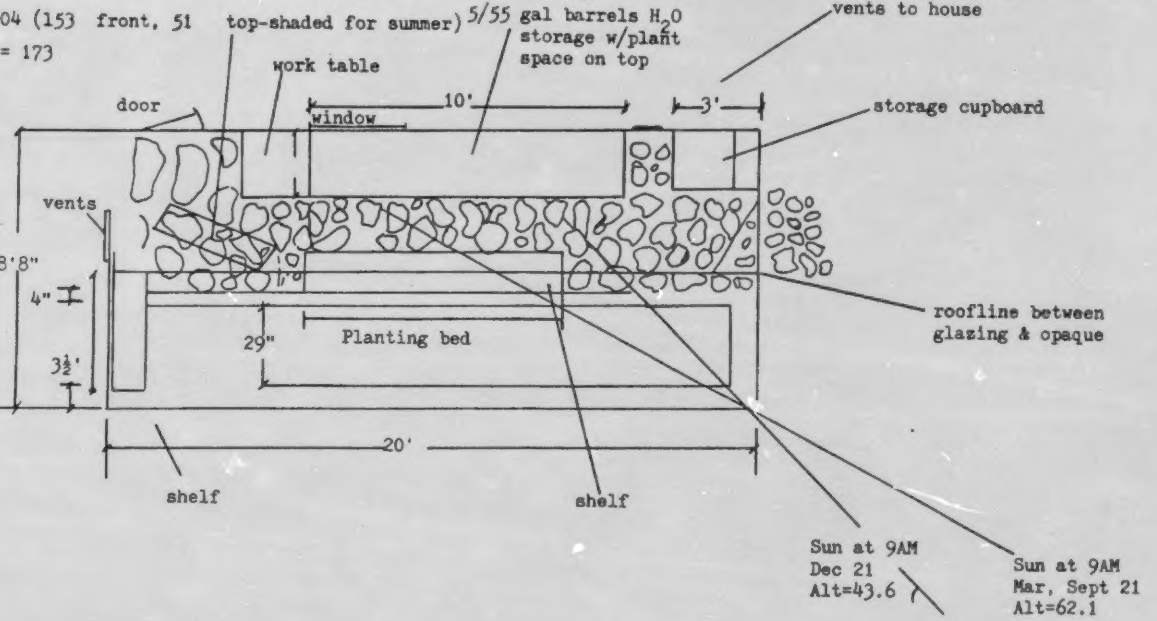
Total Vent Area = 30.6 = 15% of glazing

Ratio $\frac{\text{Upper}}{\text{Lower}} = \frac{16.9}{13.7} = 1.25/1$

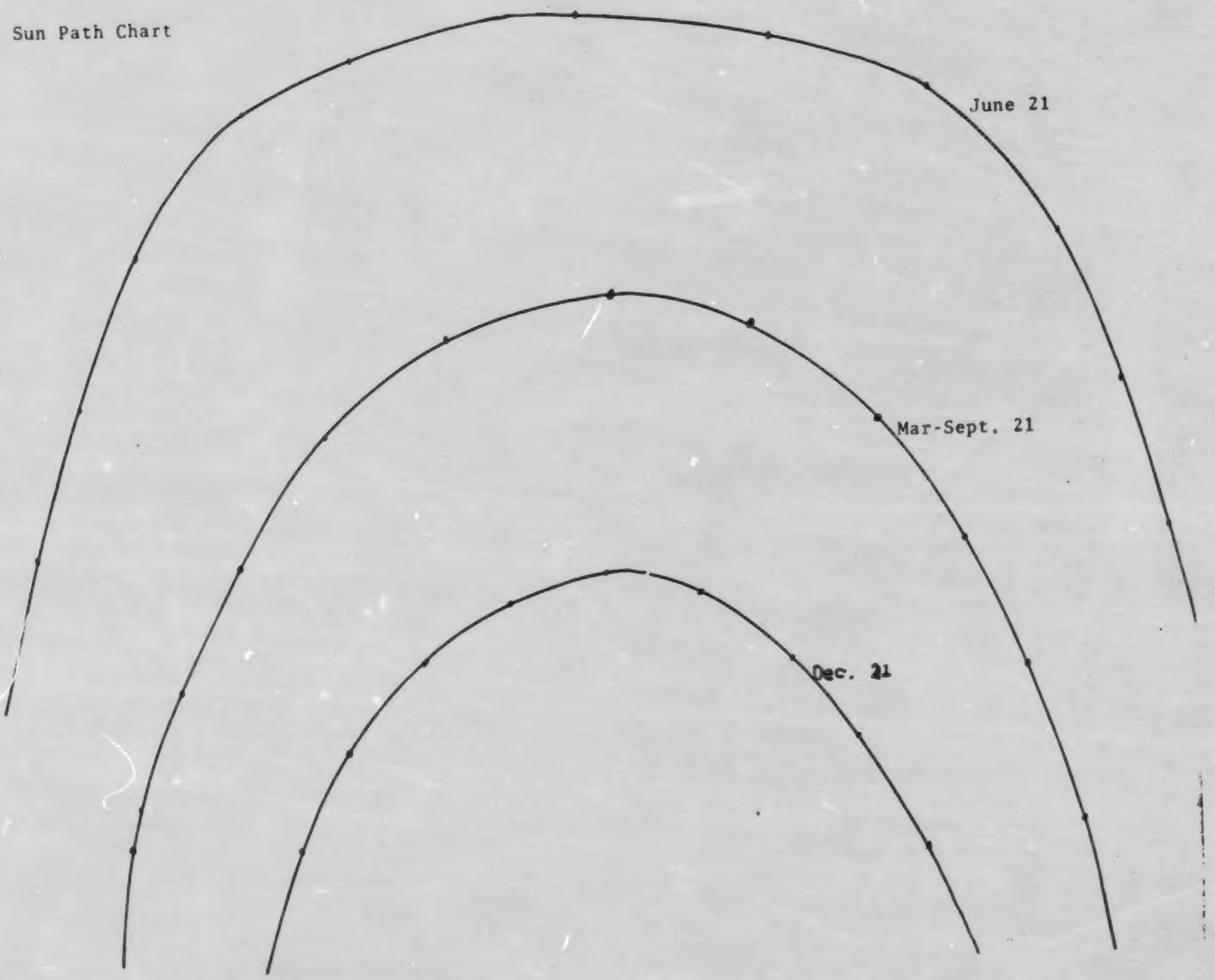
Heat Storage = 265 gallons H_2O - 5/55 gal barrels (31 ft^3 masonry & dirt in bed)

Glazing = 204 (153 front, 51 top-shaded for summer)

Floor Area = 173


5/55 gal barrels H_2O storage w/plant space on top
vents to house
work table
door
10'
window
3'
storage cupboard
vents
8'8"
4"
29"
Planting bed
3½'
roofline between glazing & opaque
20'
shelf
shelf
Sun at 9AM Dec 21 Alt=43.6
Sun at 9AM Mar, Sept 21 Alt=62.1

Sun Path Chart



MODULE: Agriculutural Applications

Lab 6: Design and Construct and Operate Solar Distillation System

Instructor Activities:

Review solar still design principles, specify location, size, and load for a model still.

Scope:

Water distillation can be divided into two categories: large scale and small scale production. For the small scale production systems (5 - 50,000 gallons per day), solar distillation is identified as being the most cost effective. A good rule of thumb design concept is that most stills have an efficiency of about 35% and can produce up to a gallon of water from $10ft^2$ (3.048 $meters^2$) of collector surface.

The solar distillation process does not imply boiling as in a commercial distillery. In the presence of a cold surface, water evaporates from the surface of warm water and condenses on the colder surface. The simples of solar water-distillation systems consists of a shallow pool of water in an enclosure having a transparent covering. This transparent covering (window) being exposed to the environment, as a collector would, will be cooler than air inside of the still enclosure. Because of the basic concepts of the greenhouse effect, the water will be warmer than the still's enclosed air. The distillation components are complete, the vapor pressure of the water saturates the still's enclosed air which is at equilibrium with the water temperature. The transparent cover (window), because of its cooler temperature, tends to limit the water to air saturation to the appropriate temperature of its surface. The distillation process is now complete, a net transfer of water from the hot to the cool transparent cover will occur.

The student working with a design team should be asked to design a simple single-effect solar water still. Once the design process is complete, the team should construct a working example of their solar water still.

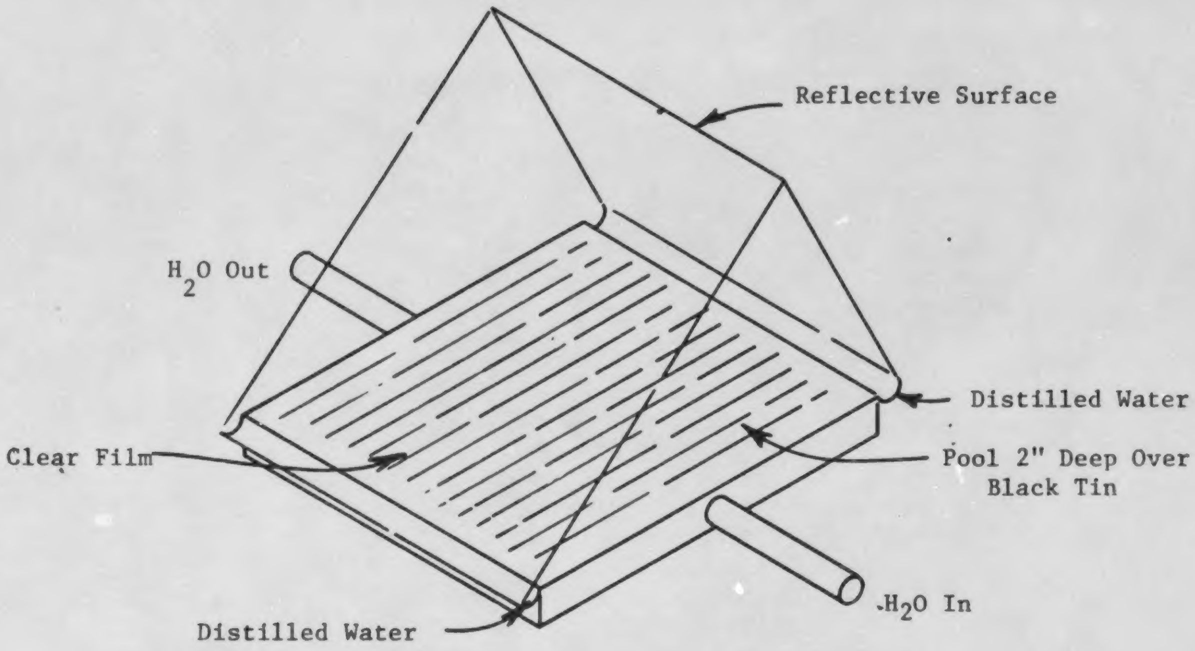
Laboratory Materials:

Grid paper, calculator, drawing board and related drafting equipment, design specifications, clear or opaque plastic, 2 x 4's, plywood, hammer, nails, saw, square, storage medium.

Process:

Design and construct a small scale solar still. Develop sketch sheets for construction, specification sheet for overview.

SOLAR STILL


Reflective Surface
H_2O Out
Distilled Water
Clear Film
Pool 2" Deep Over Black Tin
H_2O In
Distilled Water

Latitude	30 day
Average Annual Insulation	8.1×10^6 KJ/m^{2}y
Percent of Possible Sunshine	84%
Collector Efficiency	.40
Average Energy Yield to H_2O/year	2.7×10^6 KJ/m^{2}y
Heat of Vaporization (540 cal/g)	2.2×10^3 KJ/Kg
Water Yield Per Year	1.2×10^3 Kg/m^{2}y
Water Yield Per Day	3.29 Kg/m^{2}d
Value of Water @ $2/1000 gal (3785 Kg)	1.7×10^{-3} \$/m^{2}d

MODULE: Agricultural Applications

Lab 7: Size a Wind-Generator Irrigation System

Instructor Activities:

Review solar power irrigation systems, specify location, size, and load for a proposed wind generator.

Scope:

The design of wind energy conversion systems is based on the economical effective use of wind energy. Conclusively, wind energy must be able to complete a particular job less expensively, more reliably, or with fewer unacceptable side effects than any other renewable or non-renewable energy source available, capable of doing the same job. In the preliminary design, the student must recognize that the wind does not blow continuously. Therefore, the first design question which must be answered deals with availability of wind energy, then wind energy use costs, product reliability, and the minimization of unacceptable environmental side effects must be considered.

The student working with a design team, should contact a retailer dealing in wind energy conversion systems, receive a briefing on system sizing applications, then complete a sizing activity on an assigned irrigation application.

Laboratory Materials:

None.

Process:

Develop a design data sheet and specifications meeting the assigned irrigation assignment.

X-70 LAB: NON-RESIDENTIAL APPLICATIONS AND FUTURE TECHNOLOGY

(SHOW STUDENT WORK HERE)

Latitude	30 deg.
Average Annual Wind	22 @/ft^2
High	35 w/ft^2
Low	14 w/ft^2
Percent Useful	60%
Generator Efficiency	58% (Depends on system)
Average Yield	6000 Working Hours

Lab 8: Design DHW System, Meeting Load Requirements of a Neighborhood Laundry

Instructor Activities:

Review the process to be followed in the sizing activity of a commercial domestic hot water (DHW) system. Assign both local and commercial laundries and laundromats as team projects. Utilize the team approach for presentation of findings.

Scope:

The consumption of non-renewable energy by industry is speculated to be 41 percent of the total natural energy use, as compared to 25 percent in the transportation sector, 19 percent in the residential sector, and 15 percent in the commercial sector. The terminal temperature for various levels of process heat has provided two specific temperature ranges. First, identified by 18 percent of the industries surveyed as low temperature solar thermal energy system applications, those temperatures below 100°C (212°F). Second, 63 percent of the industries surveyed identified a use temperature of below 200°C (392°F), a range which could be serviced by medium range temperature collectors (concentrating collectors). Leaving 19 percent of the industries with a terminal temperature range fall above that which could be economically supplied by solar, on today's marketplace.

The student working as a design team member, should develop a domestic hot water usage instrument to be used as a design tool in the development of a commercial laundry, laundromat, or car wash solar thermal energy system.

Laboratory Materials:

None.

Process:

Select design team leader and data recorder. Approach the design problem from the usage stand point. (1) Submit individual reports and prepare an oral report. (2) Develop a DHW usage inventory.

ESTIMATING DAILY HOT WATER DEMAND

Weekly Activities

Use	No. of Uses		Gal/Use		Weekly Total
Clotheswahing					
a. Hot Wash/Hot Rinse	________	X	________	=	________
b. Hot Wash/Warm Rinse	________	X	________	=	________
c. Hot Wash/Cold Rinse	________	X	________	=	________
d. Warm Wash/Cold Rinse	________	X	________	=	________
Personal/Hygiene					
a. Hand & Face Washing	________	X	________	=	________
Miscellaneous/Wash Tub	________	X	________	=	________
			WEEKLY TOTAL:		________

$$\frac{\text{Weekly Total}}{7} = \text{DAILY TOTAL IN GALLONS}$$

*Adapt The Attached DHW Sizing Sheet

Chapter VI

SDHW SYSTEM SIZING

In order to determine the best collector and storage tank size, one has to first find out how much hot water the family uses per day. Consideration should also be given to sizing the system for the home rather than for the family. This would provide ample hot water supply for future homeowners.

The Hot Water Demand

In Arizona, it is assumed that the average family of 4 uses about 80 gallons per day-about 20 gallons per person. It is important to accurately determine the hot water use for proper system sizing. Of course, the demand varies from household to household. For this reason, Table VI-1 presents the typical amounts of hot water required for different uses. The data was obtained from Consumer Reports magazine, appliance servicemen, and by timing personal hot water usages.

By far the greatest use of hot water in the home takes place in bathing. In only one week one person taking a daily 10 minute shower will consume 240 gallons of 130 F water. The second largest consumer of hot water in the home is the washing machine. Washing four loads of laundry in an 18 pound clothes washer using a Hot Wash/Warm Rinse cycle will require 144 gallons of hot water. Then comes the dishwasher. One dishwashing cycle a day a week uses 105 gallons of hot water. From here the gallons per use drops but the list of remaining uses lengthens.

It takes about 9 cents worth of electricity to heat 10 gallons of water. If one 18-pound load of clothes is washed daily, a family could save about $90 a year at 6 cents per KWH just by switching from the Hot Wash/Warm Rinse to the Warm Wash/Cold Rinse cycle. Energy-saving showerheads can also significantly reduce hot water use without sacrificing individual comfort. Flow restrictors added to faucets can reduce overall water usage as well as hot water usage.

SOURCE: Anderson, Mary R. and John A. Kimball. Tapping the Sun: An Arizona Homeowner's Guide to Buying a Solar Domestic Hot Water System. Phoenix: Arizona Solar Energy Commission, 1980.

Table VI-1
Typical Hot Water Requirements

Use	Hot water Required (Gallons per use)		
1. Clotheswashing Machine	14 lb. machine		18 lb. machine
a. Hot Wash/Hot Rinse	38		48
b. Hot Wash/Warm Rinse	28		36
c. Hot Wash/Cold Rinse	19		24
d. Warm Wash/Cold Rinse	10		12
2. Dishwasher Machine	15		
3. Personal Hygiene			
a. Showering (ave. shower is 5 min.)	140°	130°	120°
1) Without Energy-saving Showerhead	3/min.	3.4/min	4/min.
2) With Energy-saving Showerhead	1.5/min.	1.7/min.	2/min.
b. Tub Bathing (full tub)	15	17	20
c./d. Wet Shaving/Hair Washing	2-4	2.3-4.5	2.7-5.3
e. Hand & Face Washing	1-2	1.2-2.3	1.3-2.7
4. Miscellaneous Household Uses			
a. Washing Clothes by Hand	1-2	1.2-2.3	2.7-5.3
b. Washing Dishes by Hand	4	4.5	5.3
c. Preparation of Dishes for Dishwasher	1-2	1.2-2.3	2.7-5.3
d. Miscellaneous Housecleaning	2.5	2.8	3.3
e. Food preparation using hot water	3	3.4	4

Example 1.

The Jones family consists of Mr. and Mrs. Jones and their two children, a teenager and a pre-teen. They live in a home having an 18 pound clothes washer and a dishwasher. The father takes 7 minute showers daily, The mother takes 4 minute showers daily, washing her hair separately twice a week. The teenager showers daily for 5 minutes, washing his hair in the shower as necessary. The pre-teen takes 4 (4-minute) showers a week, if the family is luck. The water tank thermostat is set at 140 F.

Using the hot water requirements from Table VI-1, we calculate first the weekly hot water usage from which we can determine the average daily hot water demand.

Example Worksheet 1

Estimating Daily Hot Water Demand for the Jones Family

Use	Weekly No. of Uses	X	Gal./Use	=	Weekly Total
1. Clotheswashing					
a. Hot Wash/Hot Rinse	0	X		=	0
b. Hot Wash/Warm Rinse	0	X		=	0
c. Hot Wash/Cold Rinse	0	X		=	0
d. Warm Wash/Cold Rinse	3	X	12	=	36
2. Dishwasher Machine	7	X	15	=	105
3. Personal Hygiene					
a. Showering	128 minutes	X	3	=	384
b. Tub Bathing	0	X		=	0
c. Wet Shaving	7	X	2	=	14
d. Hair Washing	2	X	4	=	8
e. Hand & Face Washing	50	X	1	=	50
4. Miscellaneous Household Uses					
a. Washing Clothes by Hand	1	X	2	=	2
b. Washing Dishes by Hand	0	X		=	0
c. Preparation of Dishes for Dishwasher	7	X	1	=	7
d. Misc. Housecleaning	0	X		=	0
e. Food Preparation using hot water	0	X		=	0
					606 Weekly Total

G = Daily Hot Water Use = 606 (Weekly Total) ÷ 7 = 86.5 (Daily Total in Gallons)

The weekly usage averages out to a daily demand of 86.5 gallons. This averages out to about 22 gallons per person. Had the Jones family installed energy-saving shower heads, the daily per person use would only have been 15 gallons! For this family, The energy-saving shower heads could have saved over $70 per year. A good plusating energy-saving shower head which regulates flow to 1½ gallons per minute costs about $25. Reduced water usage will also save money on a solar water system since less collector area will be needed and a smaller water tank will be required.

Now calculate your own daily hot water usage on the following worksheet:

WORKSHEET 1

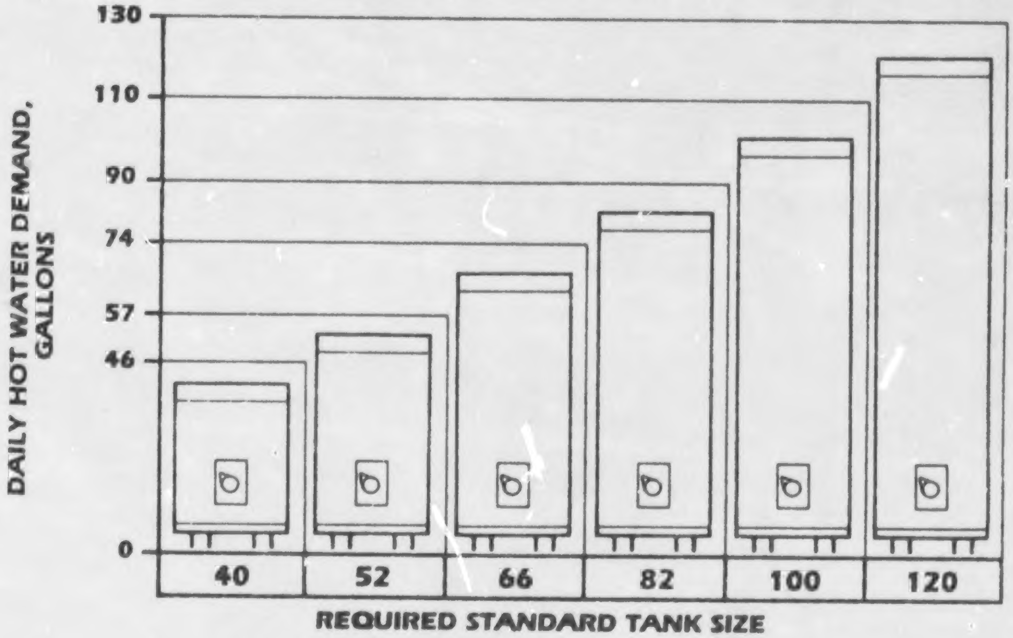
Estimating Daily Hot Water Demand

Use	Weekly No. of Uses	X	Gal./Use	=	Weekly Total
1. Clotheswashing					
a. Hot Wash/Hot Rinse		X		=	
b. Hot Wash/Warm Rinse		X		=	
c. Hot Wash/Cold Rinse		X		=	
d. Warm Wash/Cold Rinse		X		=	
2. Dishwasher Machine		X	15	=	
3. Personal Hygiene					
a. Showering	minutes	X		=	
b. Tub Bathing		X		=	
c. Wet Shaving		X		=	
d. Hair Washing		X		=	
e. Hand & Face Washing		X		=	
4. Miscellaneous Household Uses					
a. Washing Clothes by Hand		X		=	
b. Washing Dishes by Hand		X		=	
c. Preparation of Dishes for Dishwasher		X		=	
d. Misc. Housecleaning		X		=	
e. Food Preparation		X		=	
					Weekly Total

G = Daily Hot Water Use = ________ (Weekly Total) ÷ 7 = ________ (Daily Total in Gallons)

Sizing the Solar Hot Water Storage Tank

The solar tank should be sized to provide for about one day's hot water demand. Storage tanks come in standard sizes of 40, 52, 66, 82, 100 and 120 gallons. Recently, some manufacturers have started making 100-gallon tanks suitable for solar use. Figure VI-1 can be used to determine the necessary storage tank size. To do this find your daily hot water demand at the left hand side of the graph and go to the corresponding tank size to the right. If the tank size needed is between steps, the larger tank should be selected to ensure adequate quick-recovery backup and to improve the system performance (up to 7%).



TANK SIZING

STANDARD TANK SIZES

Figure VI-1 STORAGE TANK SIZING FOR SOLAR SYSTEM

Example 2.

From Figure VI-1, the Jones family with a daily demand of 86.5 gallons, would look for a 82-gallon storage tank.

A. Storage Ratio

The proper sizing of the solar hot water storage tank to the collector area is a key element for efficient and effective system performance. For most systems, this ratio is between 1.5 and 2.0 gallons of hot water storage for each square foot of collector area.

An undersized storage capacity results in raising the water temperature to its peak level too early in the day. Consequently the system is prematurely saturated. This can prevent the efficient collection of additional available solar energy during the rest of the day.

An oversized storage capacity results in a slower increase in water temperature during the day. Although the collectors operate efficiently, they may have difficulty in raising the temperature of such a large volume of water to the desired temperature. This requires the backup system to boost the temperature to the temperature level desired causing a loss of utility savings.

The Solar Collectors

Solar collectors must be sized properly to obtain an efficient system. To determine the required collector area, the hot water demand must be known. The phrase "collector area" means the gross collector area, which is the product of the length and width of the collector box.

The following are rule of thumb sizing figures for solar collectors. They assume a single-cover collector with a nonselective absorber plate, oriented south, and, in Arizona, tilted at an angle of approximately 45°.

Family or House Size	Collector Area/Sq. Ft.	
	Phoenix	Flagstaff
Family of 2 or 1-2 bedrooms	22-29	26-34
Family of 3 or 2 bedrooms	33-44	38-51
Family of 4 or 3 bedrooms	44-59	51-68
Family of 5 or 4 bedrooms	55-73	64-85
Family of 6 or 5 bedrooms	66-88	77-102

The remainder of this chapter presents a more accurate method of determining collector area.

To do this it is important to understand how to describe the performance of a solar collector. The efficiency of the collector is a measure of its ability to absorb the sun's energy and to transfer this heat energy to the collector fluid. The most popular method of determing the efficiency of solar collectors in the ASHRAE Standard 93-77 test method. The efficiency for flat plate collectors is given in terms of an equation. It is rather difficult for the average homeowner to follow. It has been included for those who wish to thoroughly cover the subject. For those who wish to skip this more technical aspect of sizing, they should move on to Collector Sizing From Graphs.

$$E = A - B\,(TF - TO)/I$$

where E = Thermal efficiency of the solar collectors,

A = Intercept on the vertical axis and is a measure of the ability of the collector to absorb solar energy and to transfer the heat to the collector fluid, (dimensionless),

B = Slope of the line and is a measure of the ability of the collector to transfer the heat to the collector fluid and its ability to reduce heat losses from the collector box to the ambient air, (Btu/[hr-ft^2°F]),

TF= Collector inlet fluid temperature and is basically the operating temperature for the collector, (°F),

TO= Outside air temperature, (°F),

I = Solar irradiation incident on the collector, (Btu/[hr ft^2° F]).

Inspection of this equation shows that an increase in the collector operating temperature, T_F, will lower the collector efficiency. A decrease in the solar irradiation will also decrease collector efficiency. Ideally, the collector should have a high value for A and a low value for B. Typical values are:

A		B (Btu/[hr – ft^2° F])	
High	0.65-0.85	High	0.90-1.5
Low	0.50-0.65	Low	0.50-0.90

The ASHRAE 93-77 data is usually available from most collector manufacturers.

Collector Sizing From Graphs

The ASHRAE Standard 93-77 test method for determining collector efficiency is also presented in the form of an easy to understand graph. A sample graph, giving the efficiency of a collector at various operating conditions is shown below in Figure VI-2. Operating conditions means the sunlight available, air temperature and inlet water temperature to the collector. Since these conditions change constantly throughout the day, there is no single efficiency value for a collector. However, there is a certain normal range of operating conditions which can be looked at and used to compare collectors.

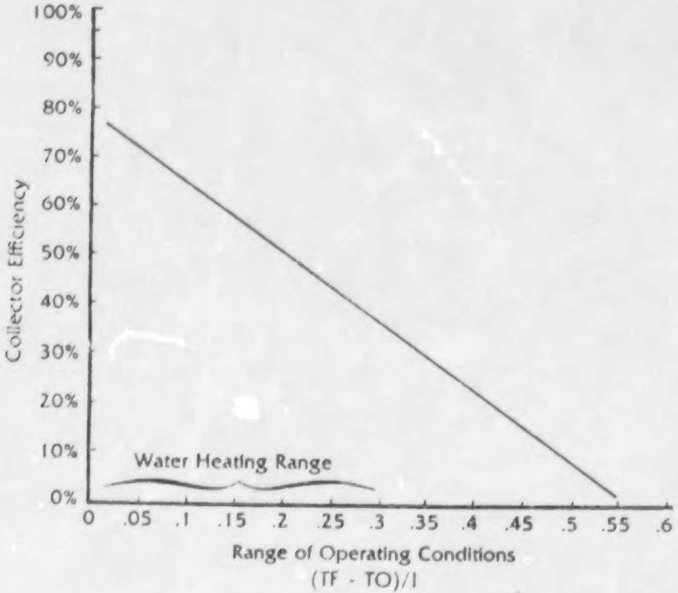


Figure VI-2 **ASHRAE 93-77 COLLECTOR EFFICIENCY CURVE** illustrating the importance of selecting the collector for its efficiency at the operating conditions for the given application.

It is important to compare the efficiencies of collectors for only the range of operating temperatures in which they will be required to perform. For domestic water heating, only the range of operating temperatures from .0 to .3 should be considered. Beyond this point operating conditions become too extreme. However, some concentrating collectors can effectively operate in this range. For example, Figure VI-2 shows a typical efficiency curve for a solar collector.

The prodedure for sizing the collector is outlined below in several steps. Worksheet 2 should be used in this procedure. Also, see the example worksheet following this discussion.

The proper size of the collector area can be estimated as follows:

Basic Collector Area = A (from Step 1 & 2)

For Phoenix and Tucson using the basic collector area A is sufficient.

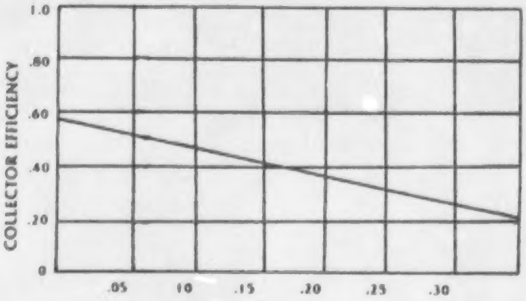
In other Arizona locations or where severe mounting problems exist or if you are willing to turn your thermostat set temperature down below 140°, a detailed collector area determination should be made.

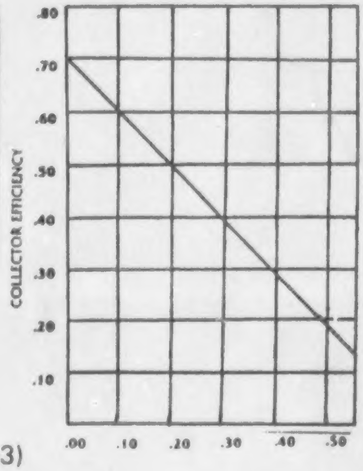
Detailed Collector Area = A x W x T x O x S

where A = Basic Collector Area (from Step 1 & 2)
W = Weather factor,
T = Tilt factor,
O = Orientation factor,
and S = Water Set Temperature factor

Basic Collector Area

- Step 1. (G and F) Estimate the family daily hot water demand G (see worksheet 1) and select the desired fraction of the hot water to be supplied from solar (called F). .82 is suggested for Arizona's desert regions and .75 for higher elevations. (See Table VI-3 for a breakdown of monthly solar fractions for desert regions.
- Step 2. (A) To determine the basic collector area A, Figure VI-3 should be used. Before using this graph a determination of the collector performance desired or being considered should be made. As has been pointed out by Figure VI-2 the average performance or efficiency of a collector can be determined by examination of a collector efficiency curve. Since the collector operating range for solar water heating systems lies between .0 and .3 on the horizontal axis of this curve, halfway or .15 would give the average collector efficiency. For example, the following are two examples of an efficiency curve from the promotional literature of two company's collectors. Looking at .15 on the horizontal axis and going up to the efficiency curve, we see that the collector on the left has an average efficiency of .68 or 68% and the collector on the right has an average efficiency of .55 or 55%. A rating of the collector's efficiency can then be made.





Efficiency		Efficiency Rating (for use of sizing graph Figure VI-3)
65% and above	=	High
50% to 65%	=	Average
50% and below	=	Low

Once the collector has been rated as high, average or low, Figure VI-3 can be used to determine the basic collector area (A). Using the preferred solar fraction (F) on the left side of the graph and choosing a collector with the desired rating, determine (X) on the horizontal axis. When this number, (X) is multiplied times (G) the gallons of hot water used per day, the result is (A) the basic collector area.

$$A = X \times G,$$

where X = Collector area to hot water daily demand ratio,
and G = Hot water used in gallons per day.

The answer will be in square feet, and it indicates the area required for properly tilted and oriented collectors in the Phoenix and Tucson areas and for providing 140°F water. For collectors not satisfying these conditions, adjustments can be made in detailed collector sizing Steps 3 thru 7.

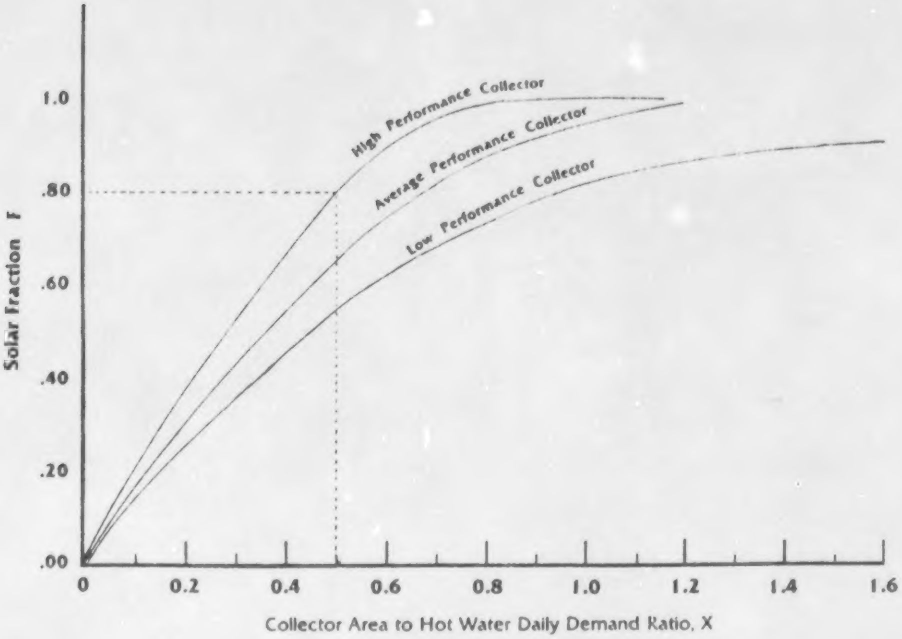


Figure VI-3 **SOLAR COLLECTOR SIZING GRAPH**

Table VI-2
Effect of Weather

City	Weather Factor (W)		
Collector Rating:	High	Average	Low
Flagstaff	1.14	1.16	1.19
Phoenix	1.00	1.00	1.00
Prescott	1.04	1.06	1.08
Tucson	1.02	1.02	1.02
Winslow	1.11	1.12	1.13
Yuma	0.96	0.96	0.96

– Step 3. (W) Select from Table VI-2 the weather factor (W) of the city nearest the house.

– Step 4. (T) Determine the latitude from Figure VI-4. If the collector tilt is going to be latitude, plus 10°, the tilt factor is 1.0. If not, determine from Figure VI-5 the tilt multiplication factor (T).

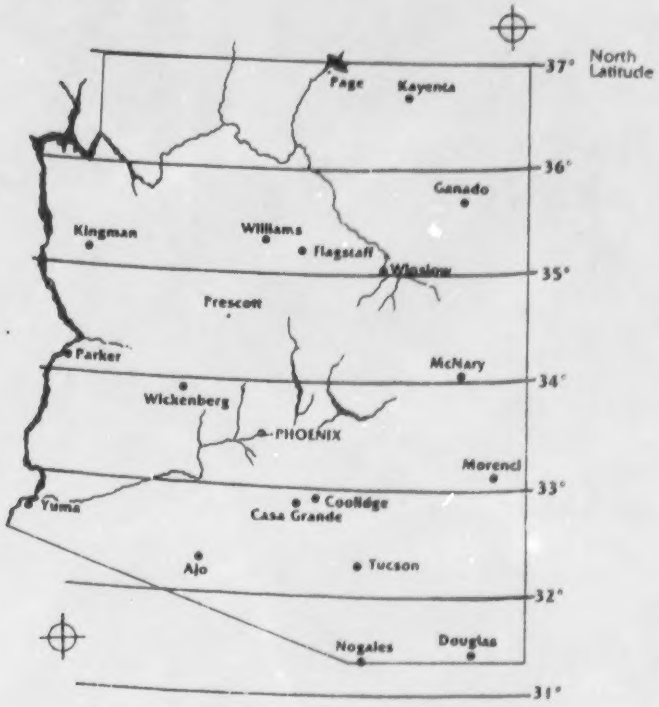

37°
North Latitude
Page
Kayenta
36°
Ganado
Kingman
Williams
Flagstaff
Winslow
35°
Prescott
Parker
McNary
34°
Wickenberg
PHOENIX
Morenci
33°
Yuma
Coolidge
Casa Grande
Ajo
Tucson
32°
Nogales
Douglas
31°

Figure VI-4 LATITUDE LINES OF ARIZONA

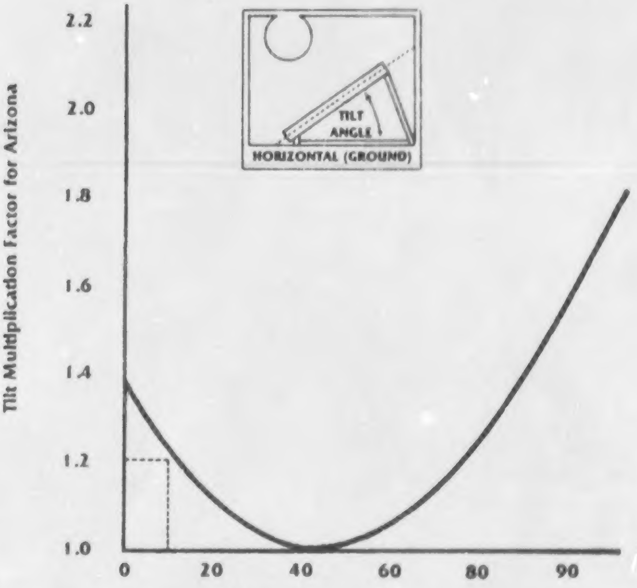


Figure VI-5 EFFECT OF COLLECTOR TILT

(The optimum collector tilt is latitude plus 10°
i.e. Phoenix latitude = 34° plus 10° = 44°)

– Step 5. (O) If the collector orientation is going to be south, the orientation factor is 1.0. If not, determine from Figure VI-6 the orientation multiplication factor (O).

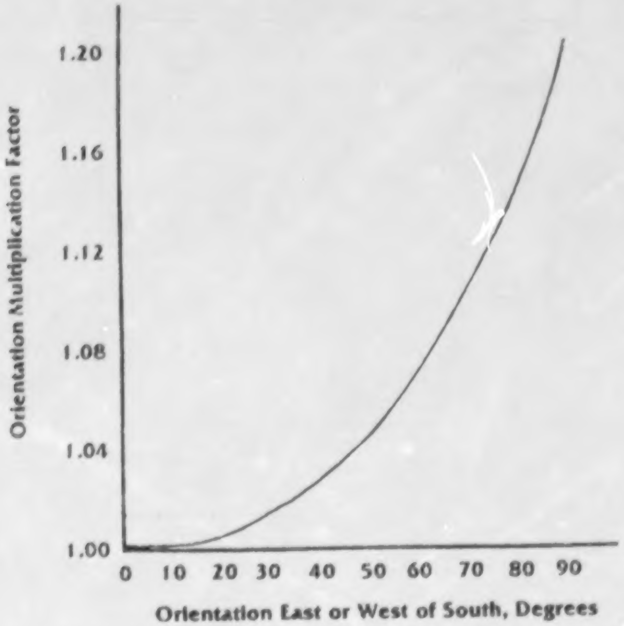


Figure VI-6 **EFFECT OF NON-SOUTH COLLECTOR ORIENTATION**

– Step 6. (S) If the water set temperature is 140°F, the water temperature factor is 1.0. If not, determine from Figure VI-7 the water set temperature multiplication factor (S).

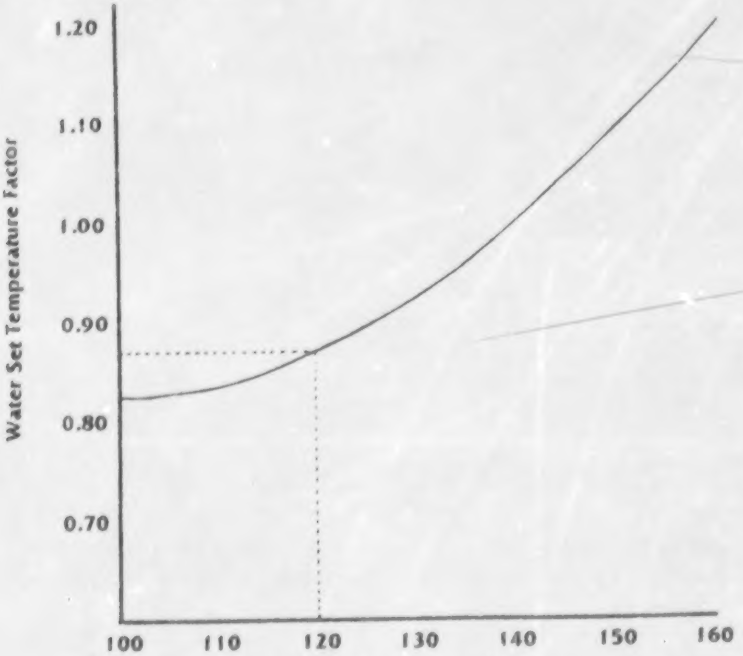


Figure VI-7 **EFFECT OF WATER SET TEMPERATURE** Water Set Temperature, F

Table VI-3

Typical Monthly Fraction of Hot Water Demand Met by SDWH Systemin Arizona Desert Area.

Month	Fraction Hot Water Demand Met By SDHW System
January	.66
February	.76
March	.83
April	.89
May	.88
June	.86
July	.85
August	.93
September	.99
October	.92
November	.77
December	.64
Year Average	.82 approximately

– Step 7. Determine the final collector area required as:

Detailed Collector Area = A x W x T x O x S,

Select a number of collector panels so that their combined area equals or slightly exceeds the calculated final area. If a heat exchanger is used in the system, the collector area should be increased 10% to 15%.

The steps and graphs are now described in detail. See the example at the end of this discussion for further clarification.

See Step 1. It should be recognized that when an F, the fraction of the hot water demand to be met by the solar system, is selected, the value is an annual average that will vary from month to month. The above table gives a typical monthly fraction of the energy to be supplied by solar that could be expected from a system meeting approximately 82% of the yearly hot water demand.

Step 2. Collector efficiency varies from manufacturer to manufacturer. Figure VI-3 presents collector efficiency curves obtained from the F CHART method by using data obtained from ASHRAE Standard 93-77 tests and the 1980 U.S. DOE Solar Collector Test Program for 163 different collectors. The water set temperature is 140°F. and the supply temperature is 60°F. Storage is 1.5 gallons per square feet of collector area.

Example 3 in this chapter describes how to read the graphs. The dotted lines on Figure VI-3 show that for an 80% solar system (F = .80) one would need .50 square feet of high performance collector for every gallon of hot water per day of demand. Thus, for the Jone's family of four with a hot water demand of about 86 gallons per day, one needs 86 x .50 = 43 square feet of high performance collector.

Step 3. The amount of sunshine and the local air and water temperature are the three important variables affecting solar collector performance.

Step 4. The best collector tilt angle for water heating is the location latitude plus

10°. This angle maximizes annual amount of sunshine falling on a flat-plate tilted collector fixed in position throughout the year. However, the effect of tilt angle variation is small so long as it is within reason. This is indicated by the tilt mutiplication factor graph for Figure VI-5. This graph is valid for all locations in Arizona. The dotted lines show that for a roof pitch of 11 degrees (corresponds to a pitch of 1 in 5), the tilt multiplication factor is only 1.2.

Step 5. The collectors should normally face south. If the collector cannot face south due to roof orientation or other structural reasons, then the collector area must be increased by the orientation factor shown in Figure VI-6. The dotted lines in Figure VI-6 show that for an orientation 30 degrees east or west of south, the orientation factor is only 1.01.

Step 6. The system calculations assumed that the water set temperature is 140°F. Significant savings can be made if the user can satisfy the hot water requirements using water at a lower temperature. For example, if the water temperature can be set at 120°F, there would be a 13% reduction in required collector area. This is illustrated by the dotted lines in Figure VI-7.

Example 3.

The Jones family of four uses 86.5 gallons of hot water per day. We wish to calculate the collector size necessary to supply 80% of the hot water at 140°F. Assume that the collectors will face south and be tilted at the proper tilt angle. Perform the calculations for Phoenix.

We assume that a high performance collector is used. 80% solar means F = .80. Since the location is Phoenix, the collector tilt and orientation are optimum, and 140°F water is desired. This example will only require determining the basic collector area (A) from Figure VI-3. Go to Figure VI-3. On the vertical (marked F) axis of the graph, find the point corresponding to F = .80 and draw a horizontal line from that point until it meets the curve marked "High". Draw a vertical line down from the curve and find the point where the vertical line intersects the horizontal axis (X). Read that point as X = .50.

This X = .50 means that for every gallon per day of hot water demand, .50 square feet of high performance collector will be needed to supply 80% of the demand from solar in Phoenix. Since the demand is 86.5 gallons of hot water per day, 86.5 x .50 = 43.2 sq. ft. of collector will be needed.

This example is now calculated on a work sheet.

Example Worksheet 2
(80% average system for 140°F water in Phoenix)

A. Determine storage tank size from Figure VI-1.
Tank Size is 82 gallons.

B. Determine collector size.

1. Estimate G on Worksheet 1. G = 86.5
Select F. F = .80

2. Select a collector from Figure VI-3 and determine X. X = .50

Determine A $\underset{X}{\underline{.50}} \times \underset{G}{\underline{86.5}} = \underset{A}{\underline{43.2}}$ A = 43.2

Generally, if the solar system is in the desert region of the state and the desired water temperature is 140°, the basic collector area (A) may be used. If not, then steps 3 thru 6 should be completed.

3. Determine weather multiplication factor from Table VI-2. W = 1.0

4. Determine tilt multiplication factor from Figure VI-5. T = 1.0

5. Determine orientation multiplication factor from Figure VI-6. O = 1.0

6. Choose water set temperature multiplication factor from Figure VI-7. S = 1.0

Detailed Collector Area = $\underset{A}{\underline{43.2}} \times \underset{W}{\underline{1}} \times \underset{T}{\underline{1}} \times \underset{O}{\underline{1}} \times \underset{S}{\underline{1}} =$ 43.2 Sq. Ft.

WORKSHEET 2
Determining Tank and Collector Size

A. Determine storage tank size from Figure VI-1 using G determined from Worksheet 1.

Tank Size is ____________ gallons.

B. Determine collector size.

1. Estimate G on Worksheet 1. G = ________
   Select F. F = ________

2. Select a collector from Figure VI-3 and determine X. X = ________

Basic Collector Area = ________ x ______ = ________ A = ________

X G A

Generally, if the solar system is in the desert region of the state and the desired water temperature is 140 , the basic collector area, (A) may be used. If not, then steps 3 thru 6 should be completed.

---

3. Determine weather multiplication factor from Table VI-2. W = ________

4. Determine tilt multiplication factor from Figure VI-5. T = ________

5. Determine orientation multiplication factor from Figure VI-6. O = ________

6. Choose water set temperature multiplication factor from Figure VI-7. S = ________

Detailed Collector Area = ______ x ______ x ______ x ______ x ______ = __________

A W T O S Sq. Ft.

MODULE: Commercial Applications

Lab 9: Design DHW System, Meeting Load Requirements for a Restaurant

Instructor Activities:

Review the process to be followed in the sizing activity of a commercial domestic hot water (DHW) system. Assign both local commercial restaurants and fast food restaurants as team projects. Utilize the team approach for presentation of findings.

Scope:

The classification of a restaurant falls into what has been established as the commercial sector of our society's work force. As in the case of the laundry, the temperature classifications for domestic water usage fall into the low temperature range, below 100°C (212°F). When developing a domestic hot water usage, survey for this commercial application; dividing out water usage by temperatures and peak demand times is very important. The student may want to be able to address the problem from two diverse stands. One being solar all the way for the total energy demands. The other being a pre-heat source to a cost efficient level of construction. The second approach may very well be the approach in today's economy which would be most acceptable.

The student working as a design team member should develop a domestic hot water usage instrument to be used to evaluate the water usage patterns after which recommendations may be provided for a domestic solar hot water system.

Laboratory Materials:

None.

Process:

Select design team leader and data recorder. Approach the design problem from the usage stand point. (1) Submit individual reports and prepare an oral report. (2) Develop a DHW usage inventory.

ESTIMATING DAILY HOT WATER DEMAND

Use	No. of Uses		Gal/Use		Weekly Total
Clotheswashing					
a. Hot Wash/Hot Rinse		X		=	
b. Hot Wash/Warm Rinse		X		=	
c. Hot Wash/Cold Rinse		X		=	
d. Warm Wash/Cold Rinse		X		=	
Dishwashing Machine		X		=	
Deep Sink Dishwashing		X		=	
Personal Hygiene					
a. Showering		X		=	
b. Hand & Face Washing		X		=	
Miscellaneous Use					
a. Dish Preparation		X		=	
b. Food Preparation (Hot Water)		X		=	

Weekly Total: ________

$$\frac{\text{Weekly Total}}{7} = \text{DAILY TOTAL IN GALLONS}$$

*Adapt the Attached DHW Sizing Exercise

MODULE: Commercial Applications

Lab 10: Design DHW System, Meeting Load Requirements for a Car Wash

Instructor Activities:

Review the process to be followed in the sizing activity of a commercial domestic hot water (DHW) system. Assign a local, commercial car wash as a team project. Utilize the team approach for presentation of findings.

Scope:

The consumption of non-renewable energy by industry is speculated to be 41 percent of the total natural energy use, as compared to 25 percent in the transportation sector, 19 percent in the residential sector, and 15 percent in the commercial sector. The terminal temperature for various levels of process heat has provided two specific temperature ranges. First, identified by 18 percent of the industries surveyed as low temperature solar thermal energy system applications, those temperatures below 100°C (212°F). Second, 63 percent of the industries surveyed identified a use temperature of below 200°C (392°F), a range which could be serviced by medium range temperature collectors (concentrating collectors). Leaving 19 percent of the industries with a terminal temperature range fall above that which could be economically supplied by solar, on today's marketplace.

The student working as a design team member is to develop a domestic hot water usage evaluation instrument to be used as a design tool in the development of a solar thermal energy system application recommendation for a commercial car wash.

Laboratory Materials:

None.

Process:

Select design team leader and data recorder. Approach the design problem from the usage stand point. (1) Submit individual reports and prepare an oral report. (2) Develop a DHW usage inventory.

ESTIMATING DAILY HOT WATER DEMAND

Weekly

Use	No. of Uses		Gal/Use		Weekly Total
Clotheswashing					
a. Hot Wash/Hot Rinse	________	X	________	=	________
b. Hot Wash/Warm Rinse	________	X	________	=	________
c. Hot Wash/Cold Rinse	________	X	________	=	________
d. Warm Wash/Cold Rinse	________	X	________	=	________
Commercial Auto Wash Equip.	________	X	________	=	________
Personal Hygiene					
a. Showering	________	X	________	=	________
b. Hand & Face Washing	________	X	________	=	________
Miscellaneous	________	X	________	=	________

Weekly Total: ________

$$\frac{\text{Weekly Total}}{7} = \text{DAILY TOTAL IN GALLONS}$$

*Adapt the Attached DHW Sizing Exercise

MODULE: Industrial Applications

Lab 11: Design DHW System, Meeting Load Requirements for a Canning Operation

Instructor Activities:

Review the process to be followed in the sizing activity of a commercial domestic hot water system. Assign a local, commercial canning operation as a team project. Utilize the team approach for presentation of findings.

Scope:

The consumption of non-renewable energy by industry is speculated to be 41 percent of the total natural energy use, as compared to 25 percent in the transportation sector, 19 percent in the residential sector, and 15 percent in the commercial sector. The terminal temperature for various levels of process heat has provided two specific temperature ranges. First, identified by 18 percent of the industries surveyed as low temperature solar thermal energy system applications, those temperatures below 100°C (212°F). Second, 63 percent of the industries surveyed identified a use temperature of below 200°C (392°F), a range which could be serviced by medium range temperature collectors (concentrating collectors). Leaving 19 percent of the industries with a terminal temperature range fall above that which could be economically supplied by solar, on today's marketplace.

The student working as a design team member is to develop a domestic hot water usage instrument to be used as a data collection tool in the development of a solar thermal energy system application recommendation for a commercial cannery.

Laboratory Materials:

None.

Process:

Select design team leader and data recorder. Approach the design problem from the usage stand point. (1) Submit individual reports and prepare an oral report. (2) Develop a DHW usage inventory.

ESTIMATING DAILY HOT WATER DEMAND

Use	No. of Uses		Gal/Use		Weekly Total
Container Washing Machine	________	X	________	=	________
Product Washing	________	X	________	=	________
Personal Hygiene					
a. Showering	________	X	________	=	________
b. Hand & Face Washing	________	X	________	=	________
Miscellaneous	________	X	________	=	________
				Weekly Total:	________

$\frac{\text{Weekly Total}}{7}$ = DAILY TOTAL IN GALLONS

*Are There Specific Temperatures Required?

*Adapt the Attached DHW Sizing Exercise.

MODULE: Pholovoltaic Collectors and Systems

Lab 12: Size Photovoltaic Power System for Irrigation

Instructor Activities:

Review the appropriate process to be followed when sizing a photovoltaic power generation station. Develop several sources for photovoltaic system components for students to utilize. Using the following simple system schematic, develop a water pump station.

Scope:

The direct conversion of solar radiation into electricity is accomplished with the photovoltaic cell. Photovoltaic cells are manufactured from various semiconductors; a semiconductor is a material that can be only a moderately good conductor of electricity. Despite much criticism, the photovoltaic cell does work. Many silicon cells have powered satellites and manned space missions and are becoming increasingly common in powering remote instrument sites and rural villages.

As of this date, a dozen companies now manufacture or distribute silicon cell modules meeting various design load characteristics.

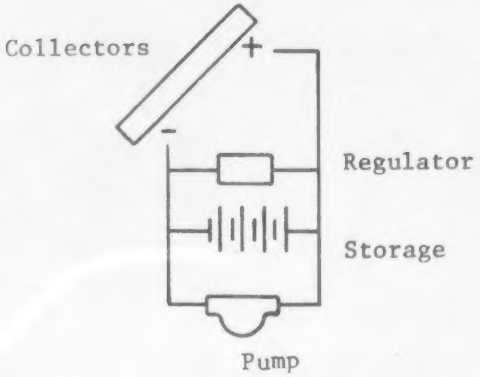
The student working as a design team member, will contact a photovoltaic retailer for the sizing activities for that specific product. The design team will then, using this products sizing recommendation, size a specific well application.

Laboratory Materials:

None.

Process:

Approach the design project from the usage stand point. Develop a project data sheet. The system design should follow the following pump schematic.



The well depth is at 150′, gallons per minute required is 60. Your assignment is to first select a pump then to size the collector array to power the system.

MODULE: Pholovoltaic Collectors and Systems

Lab 13: Complete a Comparison Evaluation of Photovoltaic Cells

Instructor Activities:

Review basic photovoltaic array applications, basic electricity.

Scope:

Each solar cell on an array will produce electrical power when exposed to sunlight. This available power can be represented by EMF and internal resistance. The output from the complete array can be represented by an EMF which is twenty times the individual series connected cells. This experiment will measure the output characteristics of the complete array. These characteristics will be expressed in a family of "current vs. voltage" curves. Each curve will represent the output produced by a given amount of solar insulation.

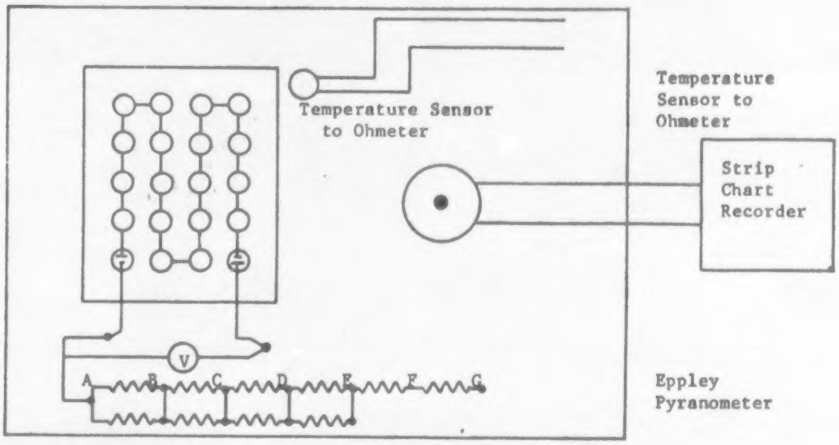
The student will work with an evaluation team, completing the assigned experiment and developing a final report.

Laboratory Materials:

20 cell solar array; digital multimeter; Eppley pyranometer; strip chart recorder; thermal barrier strips; plywood for mounting; 10 OHM, 2 watt resistor; temperature sensor.

Process:

Assemble test array as follows:



Data Presentation: Plot an individual I vs. V curve for each of the insolation levels on a single sheet of curve paper.

Calculations:

A. Determine maximum power for each curve and plot.

B. Calculate insolation in mw/cm^2 for each curve. Mark curve accordingly.

C. Calculate array efficiency at maximum power point for each insulation level.

Student Activities:

1. Prepare data sheets.
2. Measure and record resistance between terminals A and B, C, D, E, F, and G with digital ohmeter.
3. Connect digital voltmeter across output of array.
4. Orient array assembly for maximum insulation as read on pyranometer and let stabilize for 5 minutes. Read pyranometer.
5. Read temperature sensor and observe how temperature is changing, record when stabilized.
6. Measure and record array open circuit voltage.
7. Connect negative output of array to terminal A.
8. Connect positive lead of array to terminal B and read voltage vab.
9. Repeat above at terminals C, D, E, F, and G, recording data.
10. Adjust tilt of array assembly to obtain pyranometer reading 75%, 50%, and 25% of maximum reading and repeat data collection steps.

MODULE: Photovoltaic Collectors and Systems

Lab 14: Size Photovoltaic Power System for Remotely Located Residence

Instructor Activities:

Review common photovoltaic sizing practices, set up a remote photovoltaic powered residence field trip. Prepare design criteria, handout, for the installation of the system. Invite distributor of photovoltaic to present a sizing lecture to the class.

Scope:

Evaluate the remote photovoltaic installation from the commercial application stand point. Compare the design criteria to the finished installation. Evaluate the installation and identify uncommon installation applications. After observing the installation, design a remote recreation facility meeting agreed upon design criteria:

As is	800 sq/ft structure 4 - overhead light fixtures 8 - duplex outlets
Want to add	Refrigerator 2 burner stove Fm/stereo Water pump - water table 25′

Laboratory Materials:

None.

Process:

None.

PRACTICUM IN SOLAR ENERGY TECHNOLOGY

Semester Hours Credit: 3-5
Lecture: 1
Lab: 9-15

Project Director:	Charles G. Orsak, Jr.
Prime Author:	Shirley Farrow
Contributing Author:	Pearley Cunningham

Materials developed by
Navarro College
in cooperation with
The National Science Foundation
Project No. SED 80-19327.

PRACTICUM IN SOLAR ENERGY TECHNOLOGY

PREFACE:

The Practicum in **Solar Energy** Technology is an opportunity for the student to bring **together** all the engineering and scientific skills of the different courses and apply them to real situations. The framework in which this synergism can occur can have several forms. For example, the student may work in industry being paid a wage. This procedure is known as Cooperative Education. In some schools, the number of paid trainee positions may not satisfy the needs of the students and a campus or community based project may be appropriate. Although unpaid in financial terms, the experience gained in being "on their own" is very beneficial.

Regardless of the type of technical work in which the Solar Energy Technician is involved, there are certain topics related to the job market with which they should be familiar. This can be handled by a seminar held once each week. At this seminar, the students will share their experience with either jobs or projects and explore areas relevant to eventual employment. Depending upon the school, some may choose to have only a Co-op based practicum while others have only a campus based practicum. However, both options can exist at the same school. The sections below will describe guidelines for each portion of the practicum.

COURSE DESCRIPTION:

This course offers the student an opportunity for a guided work experience. This may be accomplished in either on-campus projects or off-campus activity. Off-campus work experience must have approval of both the college and the employer, and be of a significant level for a solar energy technician. Each student will develop a written agreement on activity to be done. Course credit will depend on the level and amount of time required by the activity.

COURSE PREREQUISITES:

(1) Completion of at least two semesters of Solar Energy Technology training (30 hours) and/or Instructor/Coordinator approval.

(2) Credit in Technical Communication or concurrent enrollment.

PRACTICUM IN SOLAR ENERGY TECHNOLOGY

COURSE OBJECTIVES:

Upon completion of this course the student should have developed the basic skills necessary to:

(1) Apply and refine skills and knowledge learned in the classroom to a solar related application where that knowledge may be demonstrated.

(2) Demonstrate written and oral skills in technical communication appropriate to the solar field.

REFERENCES:

(1) Cabbot, College Work Experience Education Staff Handbook, South County Community College District.

(2) Cooperative Education Student Guide, Dallas County Community College District.

(3) Cooperative Education Faculty Coordination Handbook, Maricopa County Community College District.

PRACTICUM IN SOLAR ENERGY TECHNOLOGY

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SEMINAR:

For a typical 16 week semester, this portion of the Practicum would consist of 16 one-hour seminars. Some of these should be given by representatives of industry, job service representatives, or the students themselves.

The following is a suggested seminar schedule by weeks with discussion of the content of each week. The individual college should, of course, adjust this schedule to meet the local job market needs, school calendar, and suggestions of local advisory committee.

Suggested Seminar Schedule

Week 1: Developing Practicum Objectives
Week 2: Developing Practicum Objectives
Week 3: Developing Practicum Objectives
Week 4: Conducting the Job Search
Week 5: Writing a Professional Resume
Week 6: Safety
Week 7: Communication Skills On-The-Job
Week 8: The Technical Report and Presentation
Week 9: Guest Speaker
Week 10: Time Management
Week 11: Continuing Education - When and How
Week 12: Handling Problems and Criticism
Week 13: The Interview Process
Week 14: Guest Speaker
Week 15: Student Report Presentations
Week 16: Student Report Presentations

Breakdown of Seminar Activities:

Week 1, 2, 3: Developing Practicum Objectives

During this initial period of the semester, the instructor will present the methods and techniques necessary to prepare the Practicum Agreement for signature. This agreement forms the basis for the student's work, related activities, and for the later report. Included here is a lecture module outline, "Developing Practicum Objectives" that can be used to cover this material. Samples of the agreement are contained with both the Project Option and the Cooperative Education Option materials.

Week 4: Conducting the Job Search:

The recent graduate is often confused by the process of finding a job. Many colleges have Placement Offices which will aid the student in this area. The Director of the College Placement Office, or a representative from the local Job Service Office, will usually be willing to talk to the students on this topic.

Week 5. Writing a Professional Resume

The College Placement Director, or a member of the Business or English Department at the school, should be asked to speak on how to write a resume. A useful technique here is to require the students to submit their resume and have them critiqued (in private) and returned to the student.

Week 6: Safety

This is a good opportunity to review some of the safety topics listed in other Units of the Solar Energy Technician Program. A possible speaker might be from the local OSHA office. A review of CPR techniques, tips on preventing back injury, would be appropriate topics. Students working in the field may bring up questions worth exploring during discussion.

Week 7: Communication Skills On-The-Job

Discuss how to handle the paperwork associated with an engineering technician's job in the solar field. Writing job reports, customer requests or complaints, writing bills, and filling out job applications are appropriate topics.

Week 8: The Technical Report and Presentation

An important portion of the Practicum is a written report on the activities in which the Solar Energy student was involved. Those students employed by industry would be expected to write a description of their job site, job description, and a detailed discussion of the work carried out during the cooperative experience. Those students electing a project approach should be expected to present a technical report of what activities were necessary to carry out their project. The objective of this writing would be to focus students' thinking on the application of their training. During the last weeks of the Practicum, the students should present a short presentation of their project, or work situation, to their peers. In the field of engineering technology, the ability to communicate in both written and oral form is important.

Week 9 and 14: Guest Speaker from Industry

Depending on the local community, guest speakers from industry can talk about current activities in Solar. Field trips to the local industry or solar installations could be used if possible.

Week 10: Time Management

The engineering technician, and the solar energy technician in particular, is expected to work with limited supervision. Sometimes more than one project will be involved in the technician's daily activity. By effective budgeting of on-the-job time, the productivity of the technician will be increased. A speaker from the business or industrial technology area could be recruited to present a talk in this area.

Week 11: Continuing Education - When and How

The instructor should lead a discussion in the needs for staying current in their field. How to read product literature and company supplied information should be covered. Relevant periodicals in the field and professional groups in solar that supply current information should be presented. Advancement and further educational possibilities should be covered.

Week 12: Handling Problems and Criticisms

The Solar Energy Technician must deal with not only co-workers but the public. An awareness of interpersonal relations can lead to a better understanding and handling of these situations. A member of the Psychology Department should be recruited to present an introduction to the subject area.

Week 13: The Interview Process

The College Placement Office can assist the instructor in presenting useful techniques to the students preparing for a job interview.

Week 14: Guest Speaker (See Week 9)

Week 15 and 16:

The students should be scheduled in groups of 10 to 15 to present their projects or work summaries. These should be based on the report they began during Week 8. The length may be held to 10 to 15 minutes and will enable the emerging solar energy technician to present and defend a topic in solar energy.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Identify methods of staying current on program trends.

(2) Identify activities to further develop personal skills as a potential employee.

(3) Formulate measureable work objectives and statements.

REFERENCES:

(1) Heeman, Barry, Cooperative Education in Community Colleges, Jassey-Bass Publishers, San Francisco, 1975.

(2) Cooperative Education Student Guide, Dallas County Community College District.

(3) Cabbot College Work Experience Staff Handbook, South County Community College District.

(4) Cooperative Education Faculty Coordination Handbook, Maricopa County Community College District.

UNIT TITLES:

(1) The Practicum Agreement

(2) Purpose of Objectives

(3) Writing Preliminary Draft

VOCABULARY:

NCCE - National Commission for Cooperative Education NCEA - National Cooperative Education Association

Unit 1. The Practicum Agreement

Reference 2

- A. Definition of practicum agreement - "an agreement - not a legal contract - in which industry or a sponsor, the campus, and the student agree to cooperate in an educational venture"

Reference 1, 2

- B. Who is involved
    - 1. The student
    - 2. The instructor/coordinator
    - 3. The job supervisor or project sponsor

Reference 2

- C. When the agreement terminates
    - 1. At the end of each semester (or semesters) when the learning objectives have been evaluated by the three parties involved
    - 2. At any time during the semester when mutually agreed upon by three parties involved for the following reasons:
        - a. Student drops out of school
        - b. Student drops concurrent course or practicum
        - c. Student performance not adequate
        - d. Company ceases business

Unit 2. Purpose of Objectives

- A. Establish precisely what individual student should learn from practicum course
- B. Individual considerations
    - 1. Student's level of development
    - 2. Student interest
    - 3. Career goals
- C. Establish sponsor related responsibility
- D. Establish any product or result to be accomplished

- E. Establish measure of achievement

Unit 3. Writing Preliminary Draft

- A. Major points to cover
  1. What student plans to accomplish
  2. How the student will accomplish objective
  3. How student will measure the achievement

See Attached Form

- B. Guidelines for preparing
  1. State objectives in measurable terms; avoid generalities - (words to avoid: know, understand, enjoy, appreciate, believe, see)
  2. Define each objective in terms of a single result
  3. Select language which can communicate to all parties - define any relevant terms necessary
  4. Identify new learning experiences
  5. Know what goals the training sponsor is seeking to accomplish
- C. Suggestions for writing objectives
  1. Start with action verb
  2. Identify a single key result for each objective
  3. Is the objective achievable (time of completion)
  4. State verification criteria which signal objective has been reached

5. Discussion with sponsor and trainee to identify things that need to be done

Reference 1

D. Sample objectives (See Example IX)

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Instruct and prepare student for employability.

(2) Identify the procedures for placing Co-op student.

(3) Identify procedures for placing graduate student.

(4) Identify students capable of research and development placement.

REFERENCES:

(1) Farrow, Shirley, A Guide To Job Placement, Dallas County Community College District, 1978.

(2) Heeman, Barry, Cooperative Education in Community Colleges, Jossey-Bass Publishers, San Francisco, 1975.

(3) Farrow, Shirley, Looking For a Job, Dallas County Community College District, 1978.

UNIT TITLES:

(1) Employability Skills Training

(2) Co-op Placement Procedures

(3) Permanent Placement Procedures

(4) Research and Development Opportunities

VOCABULARY:

Employability Skills

Research and Development Employment

Reference 1 & 3

Unit 1. Employability Skills Training

- A. Offer overview of job possibilities
- B. Stimulate student to a self study and self awareness
- C. Instruct the student in interview techniques and communication techniques
- D. Offer overview of work values and ethics
- E. Identify business terminology and usage
- F. Instruct in how to fill out acceptable application form
- G. Instruct student in communication through business writing
- H. Explain job benefits and wage information
- I. Explain how to keep a job
- J. Explain importance of employer/employee relationships
- K. Instill confidence by explaining expectations of the business world

Reference 2

Unit 2. Co-op Placement Procedures

- A. First interview
  - 1. Screen student for facts:
    - a. Degree plan on file
    - b. Adequate skills to handle job
    - c. Commitment to the program
    - d. Explain program and registration
  - 2. Explain program and registration
- B. Second interview
  - 1. Explore training opportunities
  - 2. Describe interview process

- C. Third interview
  - 1. Explain specifics about job
  - 2. Set up interview with training sponsor
  - 3. Follow-up with call to training sponsor as to employment of student

Reference 1

Unit 3. Permanent **Placement Upon Graduation**

- A. Use job bank for leads
- B. **Arrange** interview with student
  - 1. Job opportunities
  - 2. Student goals
- C. Follow-up
  - 1. Student report back to you on outcomes
  - 2. Follow-up student for **three** years

Unit 4. Research and Development Opportunities

- A. Select students qualified for this type of employment
- B. Counsel during final semester of school
- C. Advise employers of student availability
- D. Arrange interviews
- E. Follow-up for at least 3 years

COOPERATIVE EDUCATION OPTIONS:

The student should develop objectives to be met by the on-the-job experience and these will be incorporated into a Practicum Agreement. A sample of this agreement appropriate for a cooperative education course is included. Many business departments in community and technical colleges have active cooperative education programs. The solar instructor should seek local assistance from colleagues in that department if there are no technical co-op programs at the school.

A cooperative education effort involves at least three parties: (1) the student; (2) the instructor; and (3) the employer. Included here are topic checklists which point out the responsibilities of each in a co-op venture.

The instructor must be vigilant to assure that the student is receiving valid Solar Energy technician experience.

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Establish a viable evaluation system for the cooperative student.

(2) Administer an evaluation instrument for program evaluation by training sponsors.

REFERENCES:

(1) Cabbot College Cooperative Education Staff Handbook, South County Community College District.

(2) Northlake College Grading System, Dallas County Community College District.

(3) Northlake College Employee Evaluation Form, Dallas County Community College District.

UNIT TITLES:

(1) General Course Activities (Instructor/Coordinator)

(2) Semester/Quarter Calendar (Student)

VOCABULARY:

Sponsor
Coordinator
Trainer
Trainee

Reference 1, 3

Unit 1. General Course Activities (Instructor/Coordinator)
- A. Job development
- B. Student recruitment
- C. Student screening
- D. Complete registration of students
- E. Assign seminar time and place
- F. Plan seminar topics
- G. Trainee, instructor/coordinator, and sponsor meet on job site to discuss objectives and complete training situation agreement
- H. Trainee, instructor/coordinator, and sponsor meet for second visitation on job site to discuss student accomplishment of learning objectives. This meeting should occur during the last three weeks prior to examination week

Unit 2. Semester/Quarter Calendar (Student)
- A. Secure, complete, and return cooperative education application to Instructor/Coordinator
- B. Interview with Instructor/Coordinator
- C. Interview and obtain job
- D. Register for appropriate course
- E. First week
  - 1. Attend first seminar
  - 2. Meet with Instructor/Coordinator to discuss job or project related learning objectives
  - 3. Meet with sponsor to discuss job or project related learning objectives

F. By fourth week
    1. Confirm learning objectives
    2. Sign Practicum Agreement

G. During last three weeks of course
    1. Meet with Instructor/Coordinator and sponsor to confirm achievement of learning objectives
    2. Complete and return objectives report form to Instructor/Coordinator

INSTRUCTOR/COORDINATOR'S RESPONSIBILITIES
(CO-OP OPTION)

A. Before semester.

1. Job development.
2. Job-bank update.
3. Recruit student.
4. Interview and select students.

B. During semester.

1. Make a minimum of two job-site visits for each student. Student, sponsor, and instructor/coordinator should be present at each visit.
2. Provide 16 one-hour weekly seminars each semester.
3. Receive and review all time cards to determine whether work time requirements are met.
4. Attend advisory committees.

C. End of semester.

1. Evaluate student report.
2. Evaluate student progress.
3. Assign final grade for work done by the student on the job-site and in the seminars.

STUDENT PRACTICUM RESPONSIBILITIES
(CO-OP OPTION)

A. On-Campus and In-Classroom.

1. Apply for admission to program.
2. Interview with instructor/coordinator.
3. Turn in all reports and records on time.
4. Attend all 16 seminars and complete required seminar activities.
5. Complete Practicum Objective Form.
6. **Submit** report on Co-Op **Experiences**.

B. On-The-Job.

1. Interview for and obtain an approved training position.
2. Establish objectives with instructor/coordinator and sponsor.
3. Obtain signatures on agreement and objective forms.
4. Work number hours required of credit hours and have time cards signed by sponsor.
5. Notify employer in case of unavoidable absence.
6. Observe safety rules.
7. Observe business etiquette.
8. Cooperate with sponsor.

TRAINING SPONSOR'S RESPONSIBILITIES FOR COOPERATIVE EDUCATION

A. To the Student/Trainee.

  1. Sign a training station agreement.
  2. Assist in development of job-related learning objectives.
  3. Assist the student in achieving objectives.
  4. Verify and sign monthly time cards.

B. To the Instructor/Coordinator.

  1. Assist in development of objectives.
  2. Agree to participate in the program.
  3. Participate in a minimum of two job site visits.
  4. Participate in student evaluation.

C. To the Campus.

  1. Obey wage and hour laws and safety regulations.
  2. Provide publicity for the program whenever possible.

MODULE: INSTRUCTOR VISITATION GUIDELINES

OBJECTIVES:

Upon completion of this module, the student should be able to:

(1) Plan and organize a meaningful visitation to a job site.

(2) Identify frequency, methods, and purposes for the visitation.

(3) **Write** summary reports.

REFERENCES:

(1) Cabbot College Cooperative Education Staff Handbook, South County Community College District.

(2) Cooperative Education Faculty Coordination Handbook, Maricopa County Community College District.

UNIT TITLES:

(1) Purpose and Frequency of Visits

(2) Do's and Don'ts of Visit

(3) Guide for Making Calls

(4) Organizing Visits

(5) Summary Reports

Reference 2

Unit 1. Purpose and Frequency of Visits

- A. At least 2 calls per student per semester; more is commendable
- B. Telephone visits over and above the 2 on-site calls when needed (document phone calls)
- C. Reasons for visitation
  - 1. Explain practicum program
  - 2. Become familiar with tasks being performed by students and observe them at work
  - 3. To discuss with sponsor the types of tasks a student performs and encourage expansion to new tasks
  - 4. To secure written and oral evaluation of student's work
  - 5. To work with supervisor if a problem arises in which help is requested by either trainee or sponsor
  - 6. To finalize agreement and learning objectives and get signatures
  - 7. To keep sponsor aware of training program on campus

Reference 2

Unit 2. Do's and Don'ts of Visit

- A. Do:
  - 1. Thank employer/sponsor for time
  - 2. Review the agreement and objectives with employer/sponsor
  - 3. Meet where employer/sponsor wants to meet
  - 4. Consider the program a cooperative arrangement

B. Don't:
    1. Drop in on employer/sponsor without calling
    2. Stay longer than necessary to get information needed
    3. Talk to sponsor in front of students as if they were not there
    4. Talk to students on job or interrupt their work without sponsor's permission

Reference 1, 2

Unit 3. Guide for Making Calls
- A. Make an appointment for visitation
- B. Explain in advance the purpose of the visit
- C. Be professional and business like
- D. Be reasonable in amount of sponsor's time used
- E. Keep a written summary of call

Reference 1

Unit 4. Organizing Visits
- A. First visit
    1. Explain program
    2. Verify student objectives
    3. Advise sponsor of his role and importance (be specific)
    4. Inquire about student's exact duties
    5. Determine existing relationship between trainee and sponsor
- B. Second visit
    1. Discuss student's overall performance
    2. Determine new opportunities for learning
    3. Ask for tangible evidence indicating objectives were accomplished
    4. Have specific basis for sponsor's evaluation
    5. Encourage suggestions on curriculum and course content

6. Suggest sponsor being guest speaker at future seminars
7. Explain other services at the college as appropriate
    a. On-site training courses
    b. Placement Office
    c. Career Center
    d. Community service programs
    e. Evening classes

Unit 5. Summary Reports

A. Document visits
B. Document all telephone calls with sponsors
C. Evaluation of student report

PRACTICUM AGREEMENT
COOPERATIVE EDUCATION
JOB-RELATED LEARNING OBJECTIVES

______________________________	______________________________
Student	Employer (Company Name)
Semester & Year__________________	Course Number________________
College__________________________	Section Number_______________

Part 1 - What are you going to accomplish?
Part 2 - How are you going to accomplish it?
Part 3 - How will you measure the achievement of your objectives?

OBJECTIVE 1

Achievement
Part 1____ Yes___ No___
Part 2____
Part 3____

OBJECTIVE 2

Part 1____ Yes___ No___
Part 2____
Part 3____

OBJECTIVE 3

Part 1____ Yes___ No___
Part 2____
Part 3____

OBJECTIVE 4

Part 1____ Yes___ No___
Part 2____
Part 3____

We the undersigned agree to the validity of the objectives:

__________	__________	__________	__________________
Date	Student	Supervisor	Instructor/Coordinator

____
____

STUDENT OBJECTIVE REPORT FORM

Name____________________________________ Course No.______________

Instructor/Coordinator_____________________________ Date_________

You are required to submit a written report discussing the accomplishment of each of the agreed upon objectives. This written report must be turned in to the Instructor/Coordinator as one of the course requirements. NO CREDIT WILL BE GIVEN FOR THIS COURSE UNLESS THIS REPORT HAS BEEN SUBMITTED.

Relate how and to what extent each objective has been accomplished.

OBJECTIVE 1

How Accomplished:____

____

____

To What Extent Accomplished:____________________________________

____

____

OBJECTIVE 2

How Accomplished:____

____

____

To What Extent Accomplished:____________________________________

____

____

OBJECTIVE 3

How Accomplished:____

____

____

To What Extent Accomplished:____________________________________

____

____

OBJECTIVE 4

How Accomplished:____

____

____

To What Extent Accomplished:____________________________________

____

____

GENERAL COMMENTS:

CAMPUS/COMMUNITY BASED PROGRAM OPTION

For students electing a project, it will be necessary to identify the objectives of the project and detail what is to be done and the deadlines for completion. The project may be under the direct supervision of the Practicum coordinator or be sponsored by another faculty member or community member. In this case, the mutual agreement of all parties needs to be obtained. A document similar to that used for co-op students should be developed. An example of this agreement is presented in this section.

The enclosed list of Practicum activities are not intended to be all inclusive but to suggest the types of activities that could be done. The local situation and interests of each school should be the guiding factor in selection of Solar Energy Practicum projects.

In preparing the project plan, the student may combine several activities that will make for a project that is significant in the solar energy field. An internship with a local consulting company may be possible. This can, for example, give the student an opportunity to sample the type of work done in research and development.

The instructor/coordinator should be sure that the student has sufficiently defined the project to accomplish their goals in the time allowed. Students often have inflated goals of what can be done and the instructor's experience here can forestall any frustration later. In any project, the student's abilities should be considered strongly. Within some schools, similar courses may exist in other engineering technology and science programs and a team approach crossing discipline lines can be an excellent learning experience.

The local program advisory committee can be helpful in supplying local suggestions for projects and even some materials and equipment.

TYPICAL PRACTICUM PROJECT ACTIVITIES

1. Visit solar installations both residential/industial, reporting on merits of design.
2. Visit passive designed houses.
3. Build collector of student's design and write full manufacturer's specifications.
4. Audit performance of existing solar installation and analyze for proper operation.
5. Gather data on existing collectors.
6. Analyze and compare performance of two or more collectors such as liquid/air, flat plate/concentrator, Solar King/ LENNOX, LENNOX/Grumman, LENNOX/Revere.
7. Design system for house proposed by contractor or building owner.
8. Given a plot plan for a residential development, determine which lots should contain homes with solar:
   Select a floor plan available to customer and design system either hot water or space heating or both for home.
9. Carry out an energy audit of an existing house; indicate steps necessary to incorporate solar energy, list equipment and write bid for job.
10. Design and construct a photovoltaic system to power an emergency radio system.
11. Using federal and state guidelines, write a proposal to use your house as a demonstration project.
12. Apply for a mini-grant.
13. Present series of talks on Solar to schools or civic groups.
14. Work as advisor on solar project with school children or local community group.
15. Design Photovoltaic/Concentrator Design Criterion and build.
16. Develop a Solar Lab for Equipment.
17. Specifiy instrumentation needed to retrofit existing solar system for computerized monitoring.
18. Investigate and learn to use computer based design programs for solar sizing.

19. Construct a solar alcohol still in cooperation with Chemistry or Agriculture Departments.
20. Design a solar concentrator for steam engine in cooperation with Mechanical Engineering Technology Department.
21. Investigate the possibility of individual tracking devices for concentrating collectors.
22. Work for contractor, manufacturer or engineer as an intern.

PRACTICUM
STUDENT RESPONSIBILITIES
(CAMPUS PROJECT OPTION)

On-Campus and In-Classroom

1. Apply for admission to program.
2. Interview with Instructor/Coordinator.
3. Interview with Project Sponsor.
4. Attend all 16 seminars and complete required seminar activities.
5. Complete Practicum Project Agreement form and submit to instructor.
6. Maintain project record for periodic review by Instructor.
7. Have Project Agreement signed by: Student, Instructor, and Sponsor.
8. Establish work schedule with sponsor.
9. Observe safety rules.
10. Observe business etiquette.
11. Cooperate with sponsor.

PRACTICUM PROJECT AGREEMENT

Student Name:______________________________ Credits Earned to Date:_____
Student Number:____________________________

Course Number:__________ Credits:__________ Instructor:___________________

Project Location:____
Project Sponsor (if any):____

General Description of Project (limited to 100 words):

Student Practicum Objective:

Part 1 - What are you going to accomplish?
Part 2 - How are you going to accomplish it?
Part 3 - How will you measure the achievement of your objectives?

OBJECTIVE 1 Achievement

Part 1____ Yes___ No___
Part 2____
Part 3____

OBJECTIVE 2 Achievement

Part 1____ Yes___ No___
Part 2____
Part 3____

OBJECTIVE 3 Achievement

Part 1____ Yes___ No___
Part 2____
Part 3____

OBJECTIVE 4

Achievement

Part 1____ Yes___ No___
Part 2____
Part 3____

We the undersigned agree to the validity of the objectives:

Date	Student	Supervisor	Instructor/Coordinator

____
____

STUDENT OBJECTIVE REPORT FORM

Name______________________________ Course No.____________

Instructor/Coordinator_________________________ Date________

You are required to submit a written report discussing the accomplishment of each of the agreed upon objectives. This written report must be turned in to the Instructor/Coordinator as one of the course requirements. NO CREDIT WILL BE GIVEN FOR THIS COURSE UNLESS THIS REPORT HAS BEEN SUBMITTED.

Relate how and to what extent each objective has been accomplished.

OBJECTIVE 1

How Accomplished:______________________________

To What Extent Accomplished:______________________________

OBJECTIVE 2

How Accomplished:______________________________

To What Extent Accomplished:______________________________

OBJECTIVE 3

How Accomplished:______________________________

To What Extent Accomplished:______________________________

OBJECTIVE 4

How Accomplished:______________________________

To What Extent Accomplished:______________________________

GENERAL COMMENTS:

ERIC Clearinghouse for Junior Colleges
8118 Math-Sciences Building
University of California
Los Angeles, California 90024
AUG 5 1983